Acute Mortality and Injury of Delta Smelt Associated With Collection, Handling, Transport, and Release at the State Water Project Fish Salvage Facility

By
Jerry Morinaka
California Department of Fish and Wildlife
Bay Delta Region

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Jerry Morinaka
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Bay Delta Region
2109 Arch Airport Rd. Suite 100, Stockton, CA 95206

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Abstract

Large Delta fish-salvage facilities require the collection, handling, transport, and release (CHTR) of fish away from the immediate influence of the export pumps. Concerns that existing CHTR processes may adversely affect the survival of salvaged delta smelt and limit the benefits of new fish-screening facilities have led to a comprehensive program designed to investigate the impacts of CHTR on salvaged delta smelt and assess the potential benefits of new CHTR technologies at the State Water Project (SWP) facility. This study measured the acute mortality and injury rates of adult and juvenile delta smelt exposed to CHTR processes at the SWP's John E. Skinner Delta Fish Protective Facility during 2005 and 2006. Known numbers of marked cultured delta smelt were injected at 2 points in the CHTR process, exposed to routine operational conditions, and recovered after this process. Surviving test fish were held in controlled conditions and observed over a 48-hour period. Injury assessments were performed on all mortalities and a sub-sample of the surviving fish. Repeated trials were conducted during the adult and juvenile delta smelt entrainment period (winter-spring) using experimental releases and appropriate controls. Results indicated high survival rates for adult delta smelt (85-93%), with highly variable survival rates for juvenile fish. Both adult and juvenile delta smelt experienced low injury rates attributable to the CHTR process. These results should help assess CHTR's role in export entrainment loss, identify opportunities for facility improvements, and determine the utility of modern screening facilities as an ecosystem restoration option.

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Introduction

The John E. Skinner Delta Fish Protective Facility (Skinner Fish Facility) is operated by the Department of Water Resources (DWR) and is part of the State Water Project (SWP). The facility is located in Contra Costa County and is situated along an intake channel between Clifton Court Forebay (CCF) and the Harvey O. Banks Pumping Plant (Figure 1). The primary purpose of the facility is to remove entrained fish from the water to be exported through the SWP and return them back to the Delta away from the immediate vicinity of the pumps.

Water and fish first enter the CCF through a series of radial gates at the southeast corner of the forebay. As water is pumped by the Banks pumping plant, fish are entrained in the flow of water moving towards the Skinner Fish Facility. Fish encounter the facility's trash rack, which prevents large fish and debris from entering the facility through its vertical, 5 cm-wide openings. Fish are next guided by a series of primary louver panels into bypass pipes that lead into secondary channels. The secondary channels are used to reduce the volume of water, concentrate fish, and guide them into bypass pipes leading into large holding tanks. The length of time fish are held in these holding tanks varies according to numbers of fish, fish length, water temperature, and biological opinion requirements, but the maximum period never exceeds 24 hours. In the holding tanks, fish are concentrated and washed into a transfer bucket then hoisted and deposited into a tanker truck. Fish are trucked and returned to the Delta at one of two sites away from the immediate influence of the SWP and CVP pumps (Figure 1).

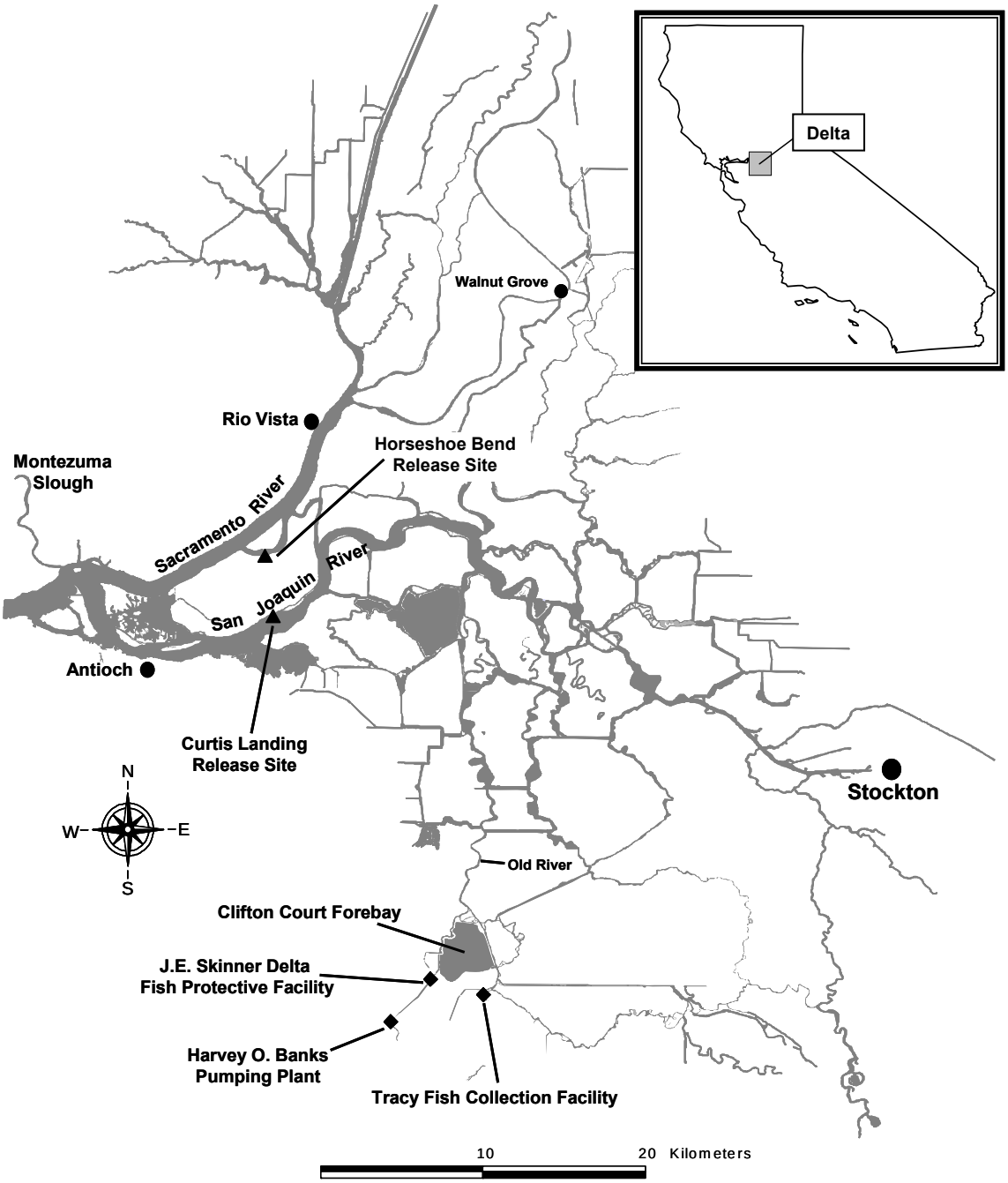

Figure 1 The location of the John E. Skinner Fish Protective Facility

Delta smelt (*Hypomesus transpacificus*) is among the 40 to 50 fish species salvaged annually at the Skinner Fish Facility. At the time of this study, delta smelt were not believed to survive the fish-salvage process (Moyle 2002). The ability of salvaged delta smelt to survive the collection, handling, transport, and release (CHTR) phases of CVP and SWP fish-salvage operations was unclear and there was considerable doubt based on the perception of delta smelt's sensitivity to handling.

Past observations of delta smelt survival have reported widely-varying results. Early observations during field collections, experimental aquaculture efforts, and general investigations of salvaged fish at the SWP's Skinner Fish Facility suggested that wild delta smelt were sensitive to handling and experienced high mortality during salvage operations. Foss (2002a) observed from the unpublished data that wild juvenile delta smelt had survival rates of 17% and 11% after 24 hours (h) for handled-fish and trucked-fish, respectively. Small-scale pilot studies at the Skinner Fish Facility examined the survival of wild juvenile delta smelt exposed to CHTR processes in 1999 and 2000 and showed low and varying levels of survival ranging from 48% in 1999 to 0% in 2000 after 48 h (Foss 2002b; Afentoulis 2002).

In contrast, other delta smelt handling studies have shown that high survival can be achieved. Morinaka (1995) conducted a pilot study at the SDFPF exposing wild adult delta smelt to CHTR processes during the winter of 1995 in which survival in 5 handling and trucking trials averaged 90% for smelt held at least 48 hours after treatment. Investigations at the CVP Tracy Fish Collection Facility (TFCF) involving secondary-screen evaluations and fish-pump evaluations reported high survival rates for both cultured delta smelt and entrained wild delta smelt. Helfrich and others (2000) reported an initial survival of 99% for wild entrained adult and juvenile delta smelt during helical fish-pump evaluations at the TFCF in 1998 and 1999. Similarly, the survival of cultured sub-adult and adult delta smelt ranged from 99 to 100% after they passed through the helical fish-pump and were then held for up to 96 hours (Helfrich and others 2003).

The 2000 CALFED Record of Decision identified the improvement or replacement of the existing fish-salvage facilities at the southern Delta intakes of the SWP and Central Valley Project as a major objective in restoring and protecting fisheries resources (CALFED 2000a, 2000b). Concerns that CHTR processes may decrease survival of salvaged delta smelt and limit the benefits of new fish screening facilities has led to a comprehensive program designed to investigate the impacts of CHTR on salvaged delta smelt and assess the potential benefits of new CHTR technologies at the state and federal water project facilities. This study measured the acute mortality and injury rates of adult and juvenile delta smelt exposed to the CH and the CHTR processes at the SWP's Skinner Fish Facility during 2005 and 2006.

The primary goal of this study was to determine if acute mortality and injury rates of adult and juvenile delta smelt exposed to the CHTR process at the Skinner Fish Facility were substantial. This study was structured to test the following hypotheses:

Hypothesis 1: Adult delta smelt survive the existing CHTR phase at high rates during their normal entrainment season.

Hypothesis 2: Juvenile delta smelt experience low survival during the existing CHTR phase during their normal entrainment season.

Hypothesis 3: The components of the existing CHTR phase contribute unequally to the observed acute mortality and injury rates of delta smelt and the overall increase of these rates during the entire CHTR process.

Hypothesis 4: Acute mortality and injury rates of delta smelt vary with the diel period.

Hypothesis 5: Adult and juvenile delta smelt survival during the CHTR phase of fish salvage are influenced by key environmental and operational factors.

Hypothesis 6: Acute mortality and injury rates of wild delta smelt differ from those of cultured delta smelt.

Note: Hypothesis 4 was not tested during the study because the pumping schedule at the Harvey O. Banks Pumping Plant had logistical issues, such as not including consistent daytime exports. During the study periods, pumping occurred at high rates during the late-night and early-morning hours. Typically, pumping is minimal or suspended during the day.

Methods

The initial study schedule called for the testing of adult delta smelt between December and March, which is the normal entrainment period for adults at the Skinner Fish Facility. Juvenile delta smelt testing was scheduled for April through early July. In 2005, delays in the completion of the CHTR test-fish building (TFB) resulted in a compressed testing schedule for adults. Adult trials were only conducted during April, and the juvenile trials from May through mid-July. During the second year (2006), adult trials were conducted from late-December 2005 through May 2006, when the cultured juvenile delta smelt reached sufficient size (25-30 mm FL) for conducting trials. Juvenile trials were conducted over a shorter period from June to mid-July 2006.

Cultured (F_1) adult and juvenile delta smelt were obtained from the UC Davis Fish Conservation and Culture Facility (FCCL) located adjacent to the Skinner Fish Facility (Figure 2). The adult and juvenile delta smelt were held in black, 550 L, circular holding tanks, and cared for by the FCCL staff until they were needed for the experimental trials. Adult delta smelt were fed a mixture of dry pellet feed (Kyowa 1000-c) and Hikari plankton. Juveniles were fed a diet of live *Artemia*.

In the 2006 trials, cultured adult delta smelt were marked with fluorochrome calcein (Sigma-Aldrich) prior to the injection trials in order to differentiate them from the wild delta smelt collected during the trials. Calcein binds to the calcified parts of the fish (e.g., fins, jaw, opercula, scales) and causes these parts to emit a bright green fluorescence when exposed to blue light and observed through an orange filter (Figure 3). The smelt were marked by immersion in a 0.5% calcein bath for 3 to 4 minutes.

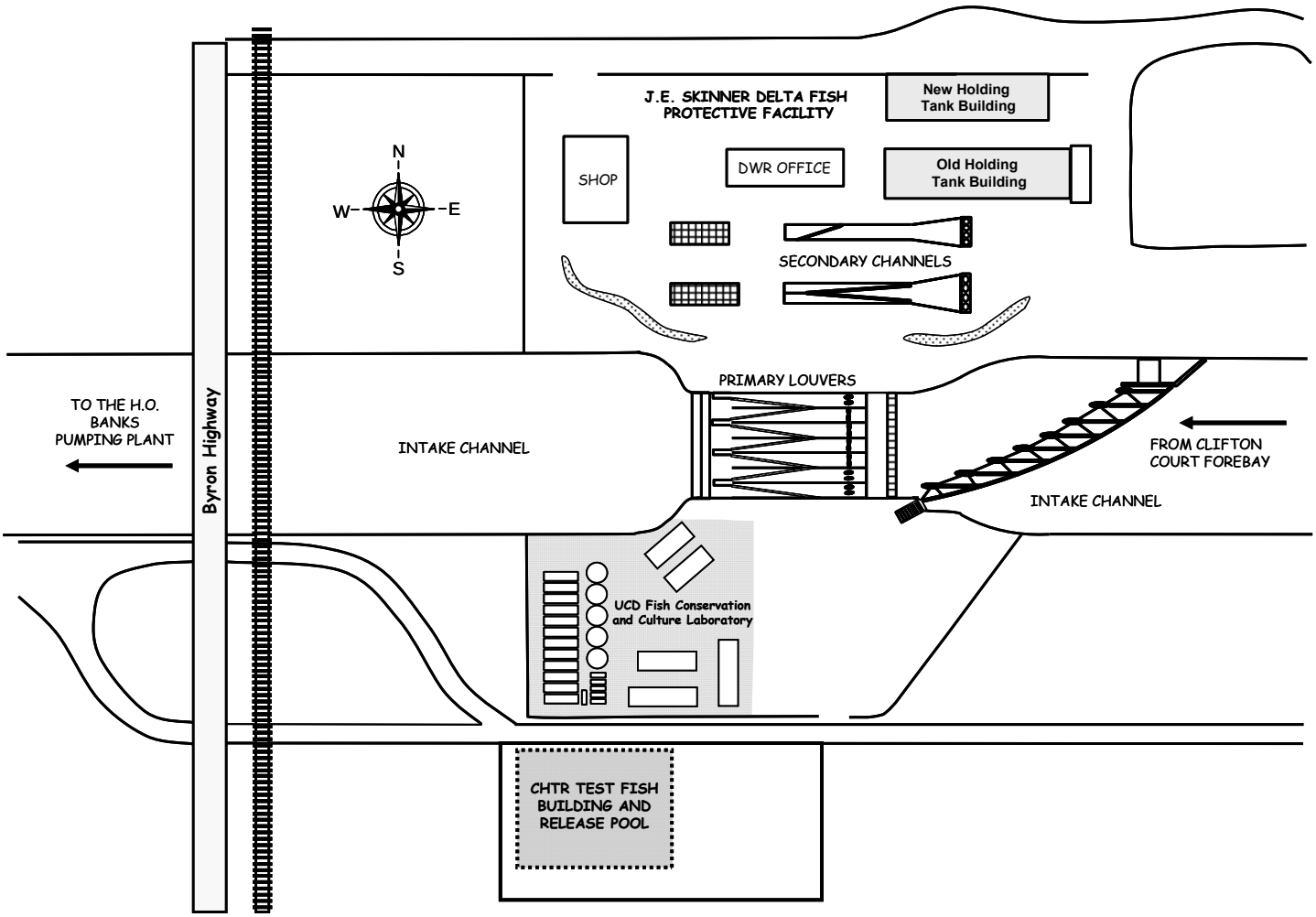

Figure 2 Diagram of the J.E. Skinner Delta Fish Protective Facility and adjacent UCD FCCL and CHTR test fish building

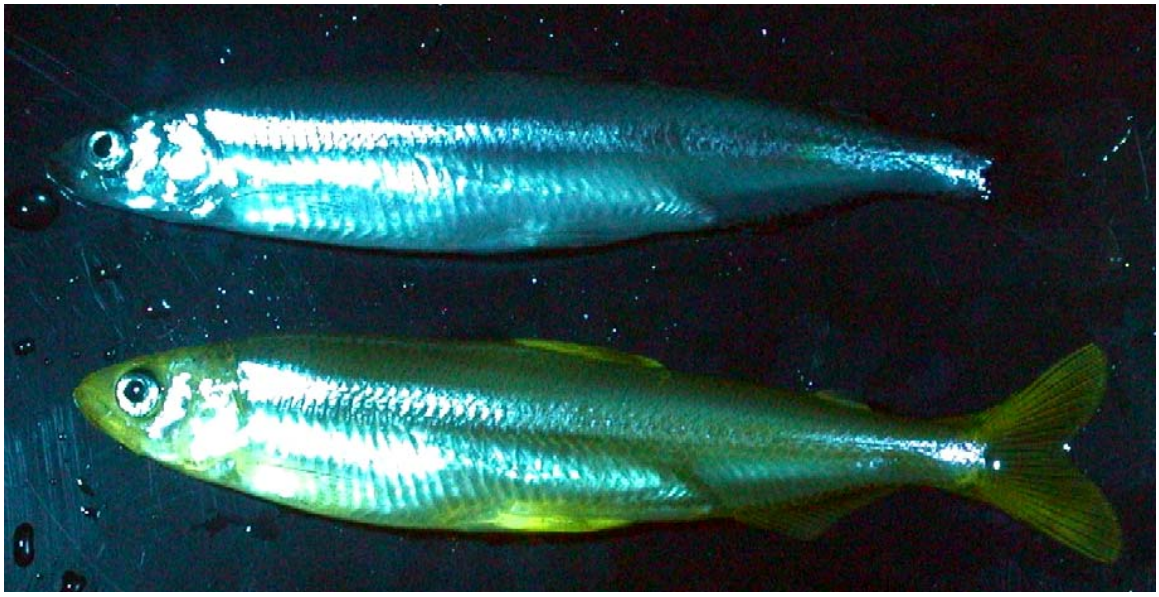

Figure 3 Photograph of adult delta smelt under filtered blue light, unmarked (top) and calcein-marked (bottom)

The juvenile delta smelt used in the 2006 trials were not marked with calcein for two reasons. First, we were not able to refine marking techniques for juvenile delta smelt in time for its use. Second, wild juvenile delta smelt were not observed in the south Delta that year. Instead, the orange coloration of the gut from being fed a diet of artemia at the UCD FCCL and the distinct melanophore markings on the ventral side of cultured juveniles were used as alternate marks for differentiating cultured fish from wild fish.

In order to determine the survival rates of adult and juvenile delta smelt (Hypotheses 1 and 2), the cultured delta smelt were exposed to 2 treatments: 1) collection and handling (CH) and 2) collection, handling, transport and release (CHTR). The 2 treatments were used to determine if specific components of the existing CHTR process had more of an influence on the acute mortality and injury rates of adult and juvenile delta smelt (Hypothesis 3). The 2005 trials injected and recovered cultured delta smelt without the presence of wild fish or debris. Conversely, the 2006 trials examined the effects of incidental wild fish and debris.

The cultured adult delta smelt used in the CH and CHTR trials ranged in age from 12 to 15 months. In 2005, the mean fork lengths (FL) of adult delta smelt were 77 mm (S = 2.41) for CH trials and 79 mm (S = 1.66) for CHTR trials. The adult delta smelt used in 2006 were slightly smaller than in 2005, averaging 70 mm (S = 5.79) for CH trials and 74 mm (S = 5.73) for CHTR trials. The cultured juvenile delta smelt used in the CH and CHTR trials ranged in age from 3 to 5 months. In 2005, the mean FL for juvenile delta smelt used in 2005 were 31 mm (S = 2.55) for CH trials and 30 mm (S = 2.09) for CHTR trials. The juvenile delta smelt used in 2006 were slightly larger than in 2005, averaging 34 mm (S = 3.43) for CH trials and 36 mm (S = 4.40) for CHTR trials.

CH Trials

At the start of each CH and CHTR trial, treatment and control-group fish were removed from a holding tank at the FCCL using soft brine shrimp nets. Twenty-five delta smelt were used for both adult and juvenile control groups in 2005 and 2006. Adult treatment groups consisted of 30 fish in 2005 and 25 fish in 2006 (due to the high recovery rates observed in 2005). Juvenile-treatment groups consisted of 40 fish for both the 2005 and 2006 trials. Control and treatment groups were counted into separate, labeled, insulated black plastic 19 L buckets partially filled with hatchery water. Each bucket was topped off with water, sealed with a lid, and placed in a foam-padded milk crate in the bed of the transport pickup. Oxygen was diffused into the water before transport.

The control group was transported the same distance as the treatment group, and then taken to the CHTR TFB. The TFB was constructed to hold control and post-treatment groups of delta smelt in separate 341 L holding tanks for 48 hours. The TFB used a sand filter and UV sterilizer to minimally treat water pumped from the CCF intake channel. An inline 10 hp chiller was used to control water temperatures during the early summer months.

The treatment group was transported to a filled salvage holding tank in the Skinner Fish Facility. The lid was removed from the transport bucket and then the bucket was lowered inside the holding tank down to the water level. Once the bucket was nearly submerged, the bottom of the bucket was lifted to perform a water-to-water release of the delta smelt. The released fish were allowed to acclimate in the holding tank for approximately 5 minutes before the drain was opened. Once the tank was drained, a 1,893 L loading bucket was lowered into the center drain of the holding tank using a 4,536 kg monorail hoist. The center cylindrical fish screen was lifted and the remaining water and fish in the tank were flushed into the partially-filled loading bucket. The loading bucket was lifted out of the holding tank and maneuvered over a rectangular 1,893 L release tank that was partially filled with a 3-inch cushion of water to emulate loading a tanker truck prior to transport to the Delta. The loading bucket was lowered and its content was released into the release tank (Figure 4). The tank was slowly drained and fish were removed and transported back to the TFB.

Figure 4 The 1,893 L loading bucket releasing fish into the 1,893 L rectangular release tank during the CH treatment

On arrival at the TFB, the fish from each treatment and control group were released into their individual black 341 L polyethylene holding tanks and held for 48 hours. Post-treatment groups of delta smelt were held under controlled conditions in the TFB. During the 2005 and 2006 trials, adults were held in water temperatures ranging from 9.6 to 19.0 ºC, while juveniles were held in water temperatures ranging from 14.0 to 23.0 ºC. Filtered CCF water was provided at a flow rate of approximately 7 to 11 liters per minute into each of the holding tanks. Water was aerated using air supplied to the tanks through air pumps and diffusing stones. Water quality measurements and mortalities were recorded at 0, 24, and 48 hours. The post-experiment holding tanks were drained at 48 hours, the remaining live fish were euthanized, and fork length measurements (mm) were recorded. The 2006 adult treatment groups were checked for calcein marks using filtered blue light to determine the presence or absence of wild delta smelt. All wild delta smelt, a sub-sample of 6 live cultured delta smelt from each control and treatment group, and all mortalities at 48 h from each tank were saved for fish-injury assessments.

During 2006, miscellaneous fish and debris were also collected and processed at the end of each trial. Miscellaneous fish were identified by species and measured (FL mm). Debris was separated into three categories: 1) green (*Egeria*, hyacinth, leaves), 2) woody (sticks, bark, twigs) and 3) other (plastic, freshwater sponge, decomposed fish). The total wet weight for each category of

debris was measured in grams and recorded onto data sheets with the miscellaneous-fish information.

Predatory fish were numerated and temporarily held when encountered during 2006 adult CH and CHTR trials. Stomach contents of predatory fish > 250 mm FL such as striped bass (*Morone saxatilis*), white catfish (*Ameiurus catus*), and channel catfish (*Ictaluras punctatus*) were collected. Predatory fish were not checked for consumed test fish during the 2006 juvenile CH and CHTR trials.

CHTR Trials

The CHTR trial procedures were identical to the CH trial procedures up to and including the draining of the salvage holding tank and concentration of fish and water into the 1,893 L loading bucket. At this point, the 4,536 kg monorail hoist was used to lift the bucket out of the salvage holding tank and maneuver it over a hatch in the 9,460 L fish truck on the opposite side of the holding tank building. The truck tank was approximately 75% pre-filled with water, and salt was added to the tank to achieve a 3 ppt salt concentration in order to reduce fish stress. The bucket was lowered and the contents of the bucket were released into the truck tank.

Once the fish truck was loaded, water was added to top off the truck tank (when needed) and the fish were transported approximately half way to the SWP fish-release sites before returning to the TFB grounds. The transport time was similar to normal fish-release hauls, approximately 50 minutes. To approximate actual release conditions, the fish truck emptied its contents through a fixed 25.4 cm by 762 cm PVC pipe (Figure 5). The contents of the fish truck were released below the water surface into a partially-filled 45,425 L CHTR release pool located adjacent to the TFB. The release-pipe length, truck orientation, and rinse water features differed from the actual SWP release facilities because of space limitations at the test site. The pool water was drained and the test fish were removed and transported into the TFB using black 19 L buckets. The CHTR post-treatment procedures were identical to the aforementioned CH procedures.

Figure 5 Fish truck backed up to the release pipe and ready to release fish from a CHTR trial into the release pool after a simulated fish haul

Environmental parameters were measured throughout the CHTR process to test against adult and juvenile survival (Hypothesis 5). These parameters were measured at the UCD FCCL when: 1) control and treatment groups were prepared for each trial, 2) before release of fish into the Skinner Fish Facility salvage holding tanks and TFB holding tanks, 3) in the fish truck before and after the fish haul, and 4) in the CHTR release pool before fish were released. Environmental parameters were also measured in each post-experiment TFB holding tank at 0, 24, and 48 hours. A multi-probe meter (YSI Model 556) was used to measure water temperature (°C), dissolved oxygen (mg/L), dissolved oxygen (%), and specific conductivity (µS/cm), while a Secchi tube (120 cm) was used to measure water clarity (cm) during the CH and CHTR trials. This tube was used for shallow or running water and utilized a Secchi pattern at the bottom of the tube that could be viewed through the column of water inside.

Post-Treatment Survival

Post-treatment survival rates for all 2005 and 2006 adult and juvenile CH and CHTR trials were calculated by dividing the number of live test fish at 0, 24, and 48 hours after the treatment by the number of fish injected to start the treatment. Adult post-treatment survival for the 2005 trials factored in any non-recovered fish (including fish lost down the drain of the Skinner Fish Facility salvage holding tank) whereas the 2006 survival factored in both non-recovered fish and losses due to predation. Juvenile post-treatment survival for the 2005 and 2006 trials factored in fish lost down the drain of the Skinner Fish Facility holding tank. Predatory fish were not checked for consumed test fish during the 2006 juvenile trials.

Injury Assessment

Injury assessments were made on a sub-sample of each control, CH, and CHTR group of delta smelt used in each adult and juvenile trial. Injury assessments were also made on all wild delta smelt for comparison with the cultured delta smelt used in the CH and CHTR trials (Hypothesis 6). At the start of each trial, quality control (QC) samples were taken from the treatment and control groups. The quality control samples consisted of 2 delta smelt randomly netted from the treatment group transport bucket prior to injection into the Skinner Fish Facility holding tank, and 2 delta smelt that were removed from the control group transport bucket prior to being released into the post-experiment holding tank at the TFB. These QC samples were used to determine if delta smelt exhibited injuries associated with the handling and transport of control and treatment groups. At 48 h post treatment, all dead delta smelt, wild delta smelt, and 6 live delta smelt from each control and treatment group were sampled for injury assessment.

After each treatment, all fish were measured (FL mm) and weighed (g wet weight). Assessment consisted of a microscopic examination of heads, eyes, bodies and fins for abnormalities, abrasion, and hemorrhaging. A stereo dissecting microscope (Olympus SZ60) was used within a zoom range of 1x to 6.3x magnification to identify injuries to adult and juvenile fish. External abnormalities were scored using a set of predefined fish-injury codes or categories (Figure 6).

CHTR Injury Data Codes

Study = Acute Mortality and Injury
Species = Delta Smelt

D = Dead
A = Alive

Head

0 = Normal
1 = One operculum missing
2 = Both operculums missing
3 = Integument missing
4 = Hemorrhage
5 = Other injury
(specify in comments)
6 = Decapitation
7 = Bubble under the skin

Eyes

0 = Normal
1 = One missing
2 = Both missing
3 = Bulging
4 = Hemorrhage
5 = Other injury
(specify in comments)
6 = Abrasion
7 = Bubble under the skin

Skin

0 = Normal
1 = Bruised areas
(e.g. dark or red areas)
2 = Partially de-skinned
3 = Split or open wound
4 = Hemorrhage
5 = Other injury
(specify in comments)
6 = Abrasion
7 = Bubble under the skin

Fin

0 = Normal, well-shaped
1 = Discolored, frayed,
< 30% erosion
2 = > 30% erosion, but visible
3 = Eroded to bases
4 = Hemorrhage
5 = Other injury
(specify in comments)
6 = Missing
7 = Bubble under the skin

Fin Type

PCF = Pectoral fin
PVF = Pelvic fin
DF = Dorsal fin
ADF = Adipose fin
ANF = Anal fin
CF = Caudal fin

Mark

0 = None
1 = Colored dorsal fin
2 = Colored anal fin
3 = Colored caudal fin
4 = Artemia (small juveniles)

Figure 6 CHTR injury data codes used for fish-injury assessments

Adult delta smelt were also examined for scale loss. Three zones (dorsal, abdominal, and caudal) on each side of the fish were examined for scale loss. Scale loss was recorded as "number of scales missing" or as "percentage of scales missing in a zone" for large areas of missing scales. Staff was trained on scoring percent scale loss in each zone prior to conducting fish-injury assessments. The number of scales in each zone of an adult fish was estimated through scale counts made on 3 random adult fish prior to the start of the study. Total scales from each zone on each fish were averaged to come up with the total number of scales per zone. For all wild fish and each of the 6 examined fish from each treatment and control group, the scale loss scores and comments were recorded on fish health-assessment data sheets. Scale-loss determination was not possible for juvenile delta smelt because many were undergoing scale development.

Juvenile Delta Smelt Holding Tank Efficiency Tests

In 2004, juvenile delta smelt holding tank efficiency tests were conducted in both the old and the new holding tank buildings at the Skinner Fish Facility to assess fish recovery efficiency in the absence of other confounding factors. These tests were used to look at the influence of operational factors on juvenile delta smelt (Hypothesis 5). Groups of 50 cultured juvenile delta smelt were injected into a holding tank filled with water. Miscellaneous fish and debris were excluded from the holding tank. The inserted fish were allowed 2-3 minutes to acclimate before the tank was drained. Once the tank was drained, the remaining fish were recovered using the normal loading-bucket procedures and the contents of the bucket were placed into the rectangular 1,893 L release tank. The tank was slowly drained and the fish were recovered, counted, and measured (FL mm). Recovery efficiency was calculated as the number of fish recovered at the end of each test divided by the number of fish injected into the holding tank and reported as a mean ±SD for all replicates in each holding tank building.

Quality Control

A YSI Model 556 multi-probe meter was used for measuring water temperature (°C), dissolved oxygen (mg/L), dissolved oxygen (%), and specific conductivity (µS/cm). The meter was calibrated for dissolved oxygen (mg/L and %) at the beginning of each day by obtaining an altimeter reading from the Byron airport. The altimeter reading was converted to barometric pressure (mm Hg) before being used in the standard calibration procedures. The meter was calibrated for specific conductance at the beginning of each field season using appropriate conductivity standards. The Acculab VI-3mg electronic balance used for weighing adult and juvenile delta smelt was calibrated daily using the factory calibration procedure with a 200 g certified weight. The Secchi tube lacked an accepted calibration procedure, however, the bottom black-and-white target plate was removed and cleaned on a regular basis throughout the study period. The accuracy of field measurements was not determined.

Staff was trained to differentiate cultured adult delta smelt from wild adult delta smelt by checking for calcein-marked fish. All delta smelt identified as wild by the staff were either immediately verified or frozen for verification within 24 h by the principal investigator. Staff was also trained on injury assessment, including the detection of external injuries, injury scoring, and determining scale loss on adult delta smelt.

Data were checked for completeness daily. Data were entered into an Access database after discrepancies were reconciled. After the Access database was checked line by line for accuracy, 10% of the data were re-checked.

Data Analysis

All survival data were grouped by life stage, treatment type, and year. The data were first checked for normality by inspecting the plotted data then using the Shapiro-Wilk test for normality in Systat. If the data sets were not normally distributed, the data were arcsine transformed (Zar 1996).

If the adult and juvenile survival data were not normally distributed after arcsine transformation, the nonparametric Kruskal-Wallis test (Zar 1996) was used to test for differences between medians. Before using the Kruskal-Wallis test, the control group data for the CH and the CHTR trials were combined in order to test against the treatment groups. Combining the control groups was necessary in order to test for differences between CH and CHTR survival (Hypothesis 3). If a significant difference was detected between the control and treatment groups, a nonparametric multiple comparison test for unequal sample sizes (Zar 1996) was used to determine which comparisons of groups were significantly different. The Spearman rank correlation was used to test the strength of the relationship between the survival of adult and juvenile delta smelt and a subset of environmental variables (Hypothesis 5). An alpha level of 0.05 was used as the criterion for statistical significance.

Similar to the survival data, all fish-injury and scale-loss data were grouped by life stage, treatment type, and year. The data were first checked for normality by plotting the data then using the Shapiro-Wilk test for normality. If the data sets were not normally distributed, the data were arcsine transformed. The data were next tested for homogeneity of variances using Levene's test for equality of variances.

Injury and scale-loss data were not normally distributed, with the exception of the 2006 adult scale-loss data. Both the QC group data and the control-group data were combined and tested against the treatment groups. Combining the control groups was necessary in order to test for differences between CH and CHTR injury and scale loss. The nonparametric Kruskal-Wallis test was used to check for differences between medians when not normally distributed. If a significant difference was detected between the control and treatment groups using the Kruskal-Wallis test, a nonparametric multiple comparison test for unequal sample sizes (Zar 1996) was used to determine which comparisons of groups were significantly different. ANOVA was used to test for differences between the QC, control, and treatment groups for the 2006 adult scale-loss data. An alpha level of 0.05 was used as the criterion for statistical significance.

Results

Water Quality

Water temperatures in the Skinner Fish Facility (salvage) holding tanks ranged from 14.4 to 16.8°C for adult CH and CHTR trials in 2005 (Appendix A). The 2006 range was greater (9.6 to 19.0°C) in the adult CH and CHTR trials due to the extended testing period which started in December 2005 and ended in early May 2006 (Appendix E). Dissolved-oxygen levels in the salvage holding tanks ranged from 8.1 to 9.6 mg/L in 2005 and from 7.9 to 11.0 mg/L in 2006 (Appendices A and E). Specific conductance in the salvage holding tanks had a greater range (101 to 458 µS/cm) in 2006 compared to a range of 222 to 306 µS/cm in 2005 (Appendices B and F).

Although juvenile trials started approximately one month later in 2006, ranges in water temperatures, dissolved oxygen levels, and specific conductance readings in the Skinner Fish Facility holding tanks were fairly similar for both 2005 and 2006. Water temperatures ranged from 17.5 to 24.1°C in 2005 and from 18.8 to 24.4°C in 2006 (Appendices C and G). Dissolved oxygen levels ranged from 6.0 to 8.7 mg/L in 2005 and from 5.8 to 8.1 mg/L in 2006 (Appendices C and G). Specific conductance readings were slightly higher in 2005 (116 to 243 µS/cm) compared to 2006 (99 to 169 µS/cm) (Appendices D and H).

Adult Trials

In 2005, recovery of adult delta smelt at the end of each treatment was high, averaging 96.1 and 93.3% for the CH and CHTR treatments respectively (Table 1). Mean survival rates at 0 and 48 h were also relatively high for both CH and CHTR treatments in 2005, averaging above 93%. No significant difference was detected in survival at 48 h among the control, CH, and CHTR groups (Kruskal-Wallis test: $H = 3.37$, $df = 2$, $p = 0.185$).

The Spearman rank correlation was used to test the strength of the relationship between survival and environmental variables (water temperature and dissolved oxygen). Overall, results were non-significant between survival and environmental variables in both CH and CHTR trials. However, a relatively strong relationship was observed between dissolved oxygen in the release pool and 48 h survival in the CHTR trials (Table 3). Scatter plots show a weak relationship between 48 h CH survival and Skinner Fish Facility holding tank water temperature and dissolved oxygen (Figures 7 and 8). Too few CHTR trials were conducted in 2005 to see any significant relationships between survival and environmental variables.

Table 1 **Mean percent recovered and mean percent survival at 0, 24, and 48 h of adult delta smelt exposed to the CH and CHTR treatments in 2005 and 2006. The Kruskal-Wallis test was used to compare percent survivals at 48 h between the control and treatment groups (p <0.05).**

Year	Group	Trials (n)	Fish (n)	Mean number of fish recovered (%)	Mean survival (%)			48 h survival *p*-value
					0 h	24 h	48 h	
2005	Control	10	226	N/A	99.6	99.1	98.7	
	CH	6	153	96.1	94.1	94.1	93.5	0.185
	CHTR	4	109	93.3	93.3	93.3	93.3	
2006	Control	45	811	N/A	99.9	99.8	99.8	
	CH	32	676	90.8	88.9	88.4	88.3	0.000
	CHTR	13	275	88.9	86.7	85.7	85.3	

Table 2 **Nonparametric multiple comparisons for the 2006 adult survival at 48 h for control, CH, and CHTR groups. Significant values, p <0.05, are indicated with an asterisk.**

Comparison	Difference between mean ranks	Standard error (SE)	Q
Control vs. CH	23.71	4.95	4.79*
Control vs. CHTR	26.25	6.75	3.89*
CH vs. CHTR	2.54	7.05	0.36

Table 3 **Spearman rank correlation coefficient, r_s, values for 2005 adult CH and CHTR trials**

			Survival		
	Trial	n	0 h	24 h	48 h
Skinner Fish Facility water temp.	CH	6	0.304	0.304	0.152
Skinner Fish Facility DO	CH	6	-0.068	-0.068	0.213
Skinner Fish Facility water temp.	CHTR	4	0.316	0.316	0.316
Skinner Fish Facility DO	CHTR	4	0.105	0.105	0.105
Release pool water temp.	CHTR	4	0.316	0.316	0.316
Release pool DO	CHTR	4	0.738	0.738	0.738

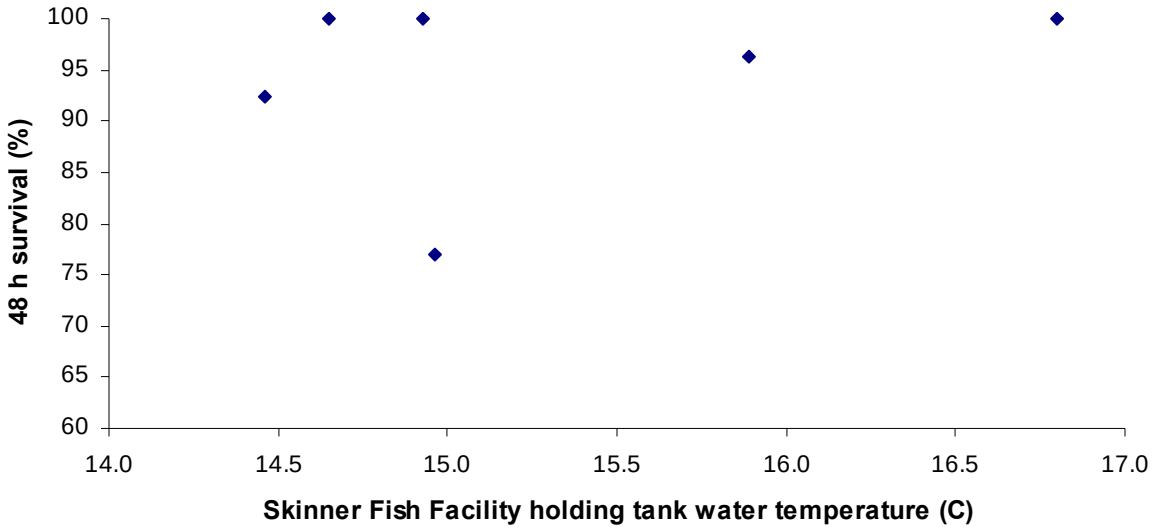

Figure 7 **Scatter plot for 48 h adult CH survival and Skinner Fish Facility holding tank water temperature in 2005**

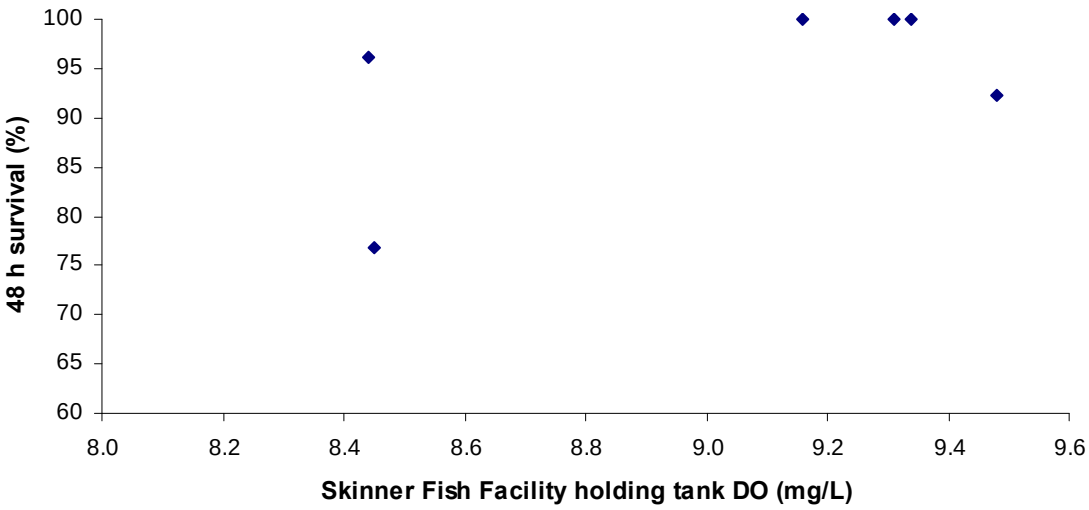

Figure 8 **Scatter plot for 48 h adult CH survival and Skinner Fish Facility holding tank dissolved oxygen in 2005**

The percentages of fish injured in 2005 were not significantly different between the QC, control, CH, and CHTR groups (Kruskal-Wallis test: H = 1.33, df = 3, p = 0.723) (Table 4). The common injuries observed were split and frayed fins. These fin injuries were also observed in many of the fish from the QC and control groups that were not exposed to the treatments. Very little scale loss was observed in any of the 4 groups (Table 5) and there were no significant differences between the QC, control, CH, and CHTR groups (Kruskal-Wallis test: H = 0.780, df = 3, p = 0.854). Many of the cultured fish started with a few missing scales and not many more scales were lost during the CH and CHTR trials.

In 2006, mean CH (90.8 %) and CHTR (88.9%) recovery rates were slightly lower than in 2005 (Table 1). Mean survival rates at 0 and 48 h were also lower in 2006, and testing revealed a significant difference in survival among the control and treatment groups at 48 hrs (Kruskal-Wallis test: H = 29.41, df = 2, p = 0.000). Multiple comparison testing revealed that survivals at 48 h were significantly different between the control and the CH groups and also between the control and CHTR groups (Table 2). The CH and CHTR groups did not significantly differ.

The Spearman rank correlation results showed several moderate and significant relationships between survival and environmental variables (water temperature and dissolved oxygen) in the 2006 CH and CHTR trials (Table 6). Figures 9 and 10 show significant moderate negative relationships between 48 h CH and CHTR survival and Skinner Fish Facility holding tank water temperature. Figure 11 shows a significant moderate positive relationship between 48 h CHTR survival and fish truck (post-fish haul) dissolved oxygen, while Figure 12 shows a significant moderate negative relationship between 48 h CHTR survival and release pool water temperature.

Table 4 **Mean percent injury by type for adult delta smelt exposed to the CH and CHTR treatments in 2005 and 2006. The Kruskal-Wallis test was used to compared the percentages of fish injured for the QC, control, and treatment groups in 2005 and 2006.**

Year	Group	Fish (n)	Percent injured by injury type				Percent of fish injured	*p*-value
			Head	Eyes	Skin	Fins		
2005	QC	38	2.6	0.0	0.0	5.3	7.5	0.723
	Control	58	0.0	0.0	0.0	6.9	6.7	
	CH	35	0.0	0.0	2.9	11.4	13.5	
	CHTR	24	0.0	0.0	0.0	12.5	12.5	
2006	QC	176	1.1	4.6	2.8	36.9	41.1	0.628
	Control	264	3.4	1.9	3.4	30.3	33.3	
	CH	184	0.5	1.1	4.9	30.4	34.6	
	CHTR	75	6.7	2.7	6.7	37.3	41.2	

Table 5 **Mean percent scale loss for adult delta smelt exposed to the CH and CHTR treatments in 2005 and 2006. The Kruskal-Wallis test was used to compare the descaling rates between the QC, control, and treatment groups in 2005. ANOVA was used to compare mean descaling rates in 2006.**

Year	Group	Fish (n)	Mean descaling (% of body)	*p*-value
2005	QC	38	0.1	0.854
	Control	58	0.1	
	CH	35	0.1	
	CHTR	24	0.3	
2006	QC	176	0.4	0.152
	Control	264	0.4	
	CH	184	0.6	
	CHTR	75	0.6	

Table 6 **Spearman rank correlation, r_s, values for 2006 adult CH and CHTR trials. Significant values, * p <0.05, ** p <0.005.**

	Trial	n	Survival		
			0 h	24 h	48 h
Skinner Fish Facility water temp.	CH	32	-0.544	-0.534	-0.531**
Skinner Fish Facility DO	CH	32	0.215	0.190	0.181
Debris	CH	32	0.092	0.064	0.058
Misc. fish	CH	32	-0.229	-0.239	-0.231
Skinner Fish Facility water temp.	CHTR	13	-0.559	-0.665	-0.688*
Skinner Fish Facility DO	CHTR	13	0.295	0.239	0.234
Fish truck water temp. (pre-fish haul)	CHTR	13	-0.156	-0.273	-0.300
Fish truck DO (pre-fish haul)	CHTR	13	0.518	0.557	0.580*
Fish truck water temp. (post-fish haul)	CHTR	13	-0.524	-0.625	-0.659*
Fish truck DO (post-fish haul)	CHTR	13	0.652	0.745	0.758*
Release pool water temp.	CHTR	13	-0.568	-0.659	-0.685*
Release pool DO	CHTR	13	0.587	0.606	0.604*
Debris	CHTR	13	0.266	0.404	0.444
Misc. fish	CHTR	13	0.096	-0.091	-0.119

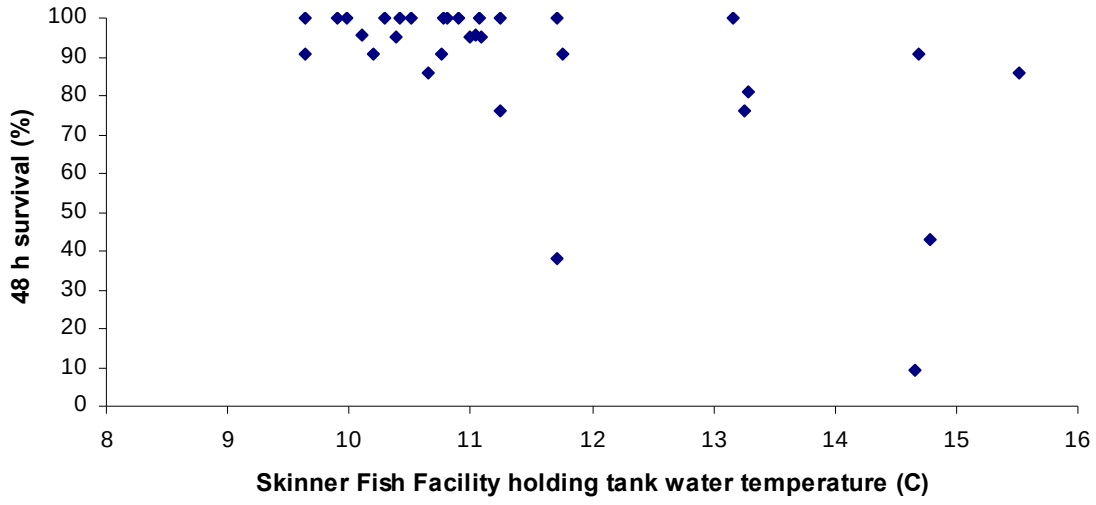

Figure 9 **Scatter plot for 48 h adult CH survival and Skinner Fish Facility holding tank water temperature in 2006**

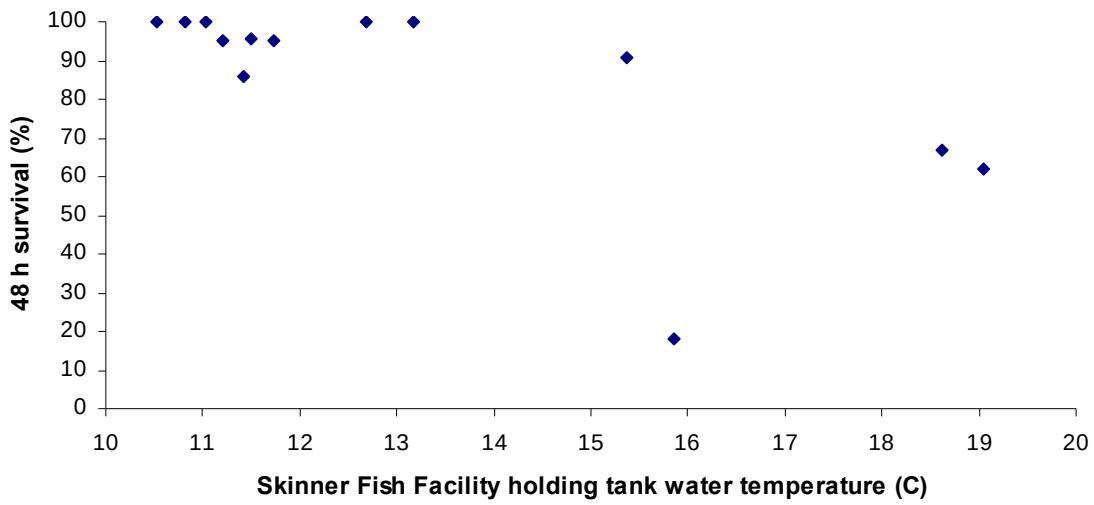

Figure 10 **Scatter plot for 48 h adult CHTR survival and Skinner Fish Facility holding tank water temperature in 2006**

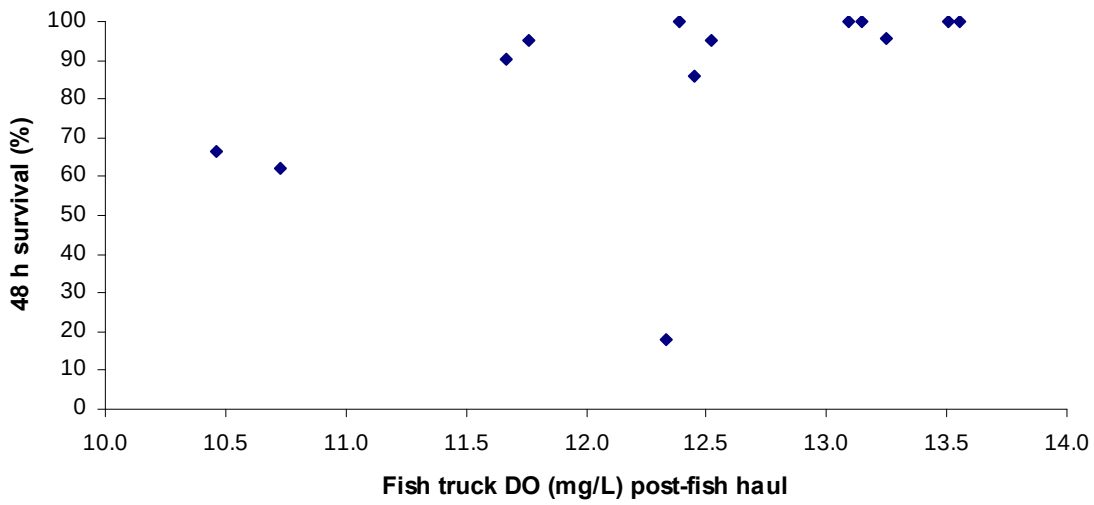

Figure 11 **Scatter plot for 48 h adult CHTR survival and post-fish haul fish truck dissolved oxygen in 2006**

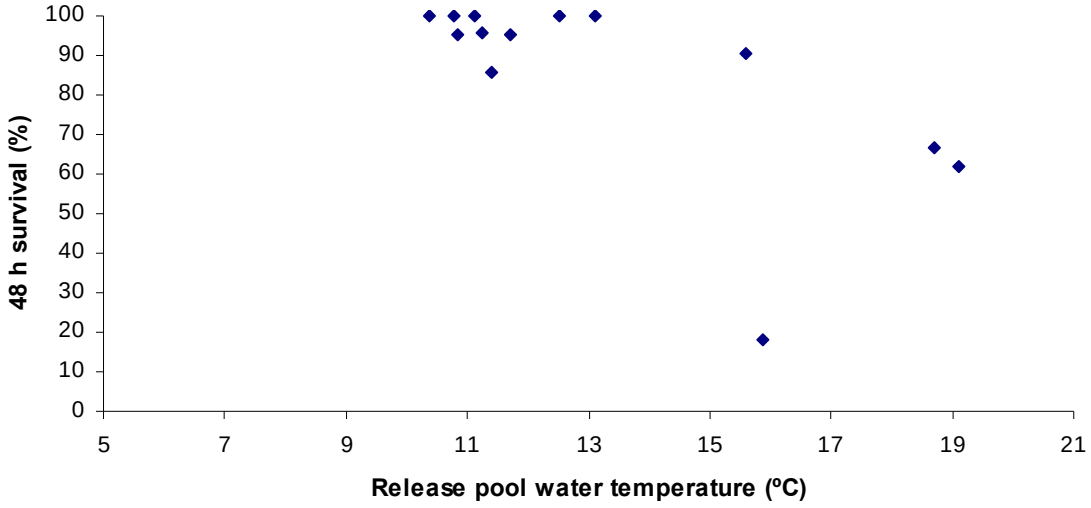

Figure 12 Scatter plot for 48 h adult CHTR survival and release pool water temperature in 2006

The percentages of fish injured in 2006 (Table 4) were not significantly different between the QC, control, CH, and CHTR groups (Kruskal-Wallis test: $H = 1.74$, $df = 3$, $p = 0.628$). Mean percent scale loss for the CH and CHTR groups was higher in 2006 than in 2005, but remained less than 1% for both treatments (Table 5). No significant difference was detected in mean scale loss between the QC, control, CH, and CHTR groups (ANOVA: $F = 1.79$, $df = 3,131$, $p = 0.152$) in 2006. Similar to 2005, many of the cultured fish started with a few missing scales and not many more scales were lost during the CH and CHTR trials.

Wild Adult Delta Smelt

A total of 29 wild adult delta smelt were collected during the 2006 trials: 20 during the CH trials and 9 during the CHTR trials. All fish were recovered alive after the CH and CHTR treatments and remained alive for the entire post-treatment period (48 h). The mean percent scale losses for the CH and CHTR trials were 3.4 and 2.6%, respectively. The mean percent of fish injured from the CH and CHTR treatments were 40 and 44%, respectively. Injuries observed included split fins and hemorrhaging near the head, pectoral, and pelvic fins. Incidences of scale losses and injury in wild fish were essentially the same as observed in test delta smelt from culture.

Predation

Predation was observed from late March to early May in 2006. Predatory fish consumed 38 injected delta smelt during 5 out of 32 CH trials (16% of trials) and 3 out of 13 CHTR trials (23% of trials). The only predatory fish species that consumed delta smelt was striped bass (223 to 490 mm FL). During one CH trial in March 2006, nine delta smelt were found in the stomach of a 308 mm (FL) striped bass. During one CHTR trial in April 2006, nine striped bass (278 to 409 mm FL) consumed 78% (18 of 23) of the delta smelt that were injected at the start of the trial. Thirty-eight fish for all trials combined (CH and CHTR) were lost to predation. The remaining 55 non-recovered fish were likely lost during the draining process within the Skinner Fish Facility.

Juvenile Trials

In 2005, mean recovery rates were 86.2 and 72.7% for the 2005 CH and CHTR trials respectively (Table 7). Mean recovery rates also increased along with the size (FL mm) of the fish for each treatment. Mean survival rates at 48 h were 61.3% for the CH trials and a much lower 37.4% for the CHTR trials. A significant difference was detected for survival at 48 h among the control and treatment groups (Kruskal-Wallis test: $H = 17.25$, $df = 2$, $p = 0.000$). Multiple comparison testing revealed that the mean survival was significantly different between the control and the CH group (Table 8). There was no significant difference between the control and CHTR groups and also the CH and CHTR groups.

No significant relationships were detected while using the Spearman rank correlation to test between survival and individual environmental variables (water temperature, dissolved oxygen, and water clarity) for 2005 (Table 9). A non-significant and negative relationship was observed between 48 h CH survival and the Skinner Fish Facility holding tank water clarity (Figure 13). Non-significant and negative relationships were observed when 48 h CHTR survival was tested against pre-fish truck water temperature (Figure 14), Skinner Fish Facility holding tank water clarity (Figure 15), and release pool water clarity (Figure 16).

Table 7 **Mean percent recovered and mean percent survival of juvenile delta smelt at 0, 24, and 48 h exposed to the CH and CHTR treatments in 2005 and 2006. The Kruskal-Wallis test was used to compare the percent survivals at 48 h between control and treatment groups (p <0.05).**

Year	Group	Trials (n)	Fish (n)	Mean number of fish recovered (%)	Mean survival (%)			48 h survival *p*-value
					0 h	24 h	48 h	
2005	Control	21	482	N/A	98.1	83.4	82.0	
	CH	13	467	86.2	71.8	62.6	61.3	0.000
	CHTR	8	288	72.7	50.6	38.8	37.4	
2006	Control	22	511	N/A	99.6	92.0	85.9	
	CH	15	578	86.6	80.2	54.6	50.9	0.000
	CHTR	7	254	88.8	78.4	61.4	57.9	

Table 8 **Nonparametric multiple comparisons of the 2005 juvenile survival at 48 h for control, CH, and CHTR groups. Significant values, p <0.05, are indicated with an asterisk.**

Comparison	Difference Between Mean Ranks	Standard Error (SE)	Q
Control vs. CH	19.53	4.33	4.52*
Control vs. CHTR	11.90	5.09	2.34
CH vs. CHTR	7.63	5.51	1.38

Table 9 **Spearman rank correlation coefficient, r_s, values for 2005 juvenile CH and CHTR trials**

	Trial	n	Survival		
			0 h	24 h	48 h
Skinner Fish Facility water temp.	CH	13	0.207	-0.099	-0.104
Skinner Fish Facility DO	CH	13	-0.394	-0.242	-0.192
Skinner Fish Facility holding tank secchi	CH	13	-0.342	-0.534	-0.545
Skinner Fish Facility water temp.	CHTR	8	-0.359	-0.452	-0.452
Skinner Fish Facility DO	CHTR	8	0.180	0.310	0.310
Fish truck water temp. (pre-fish haul)	CHTR	8	-0.572	-0.683	-0.683
Fish truck DO (pre-fish haul)	CHTR	8	-0.078	-0.180	-0.180
Fish truck water temp. (post-fish haul)	CHTR	8	-0.216	-0.286	-0.286
Fish truck DO (post-fish haul)	CHTR	8	-0.491	-0.405	-0.405
Release pool water temp.	CHTR	8	-0.096	-0.238	-0.238
Release pool DO	CHTR	8	-0.024	-0.048	-0.048
Skinner Fish Facility holding tank secchi	CHTR	8	-0.575	-0.595	-0.595
Release pool secchi	CHTR	8	-0.683	-0.714	-0.714

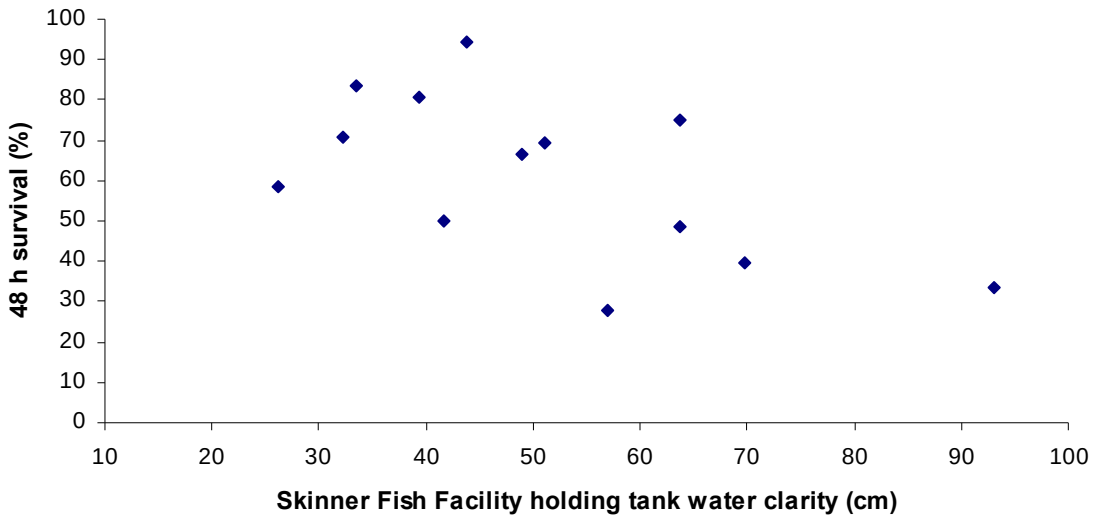

Figure 13 **Scatter plot for 48 h juvenile CH survival and Skinner Fish Facility holding tank water clarity in 2005**

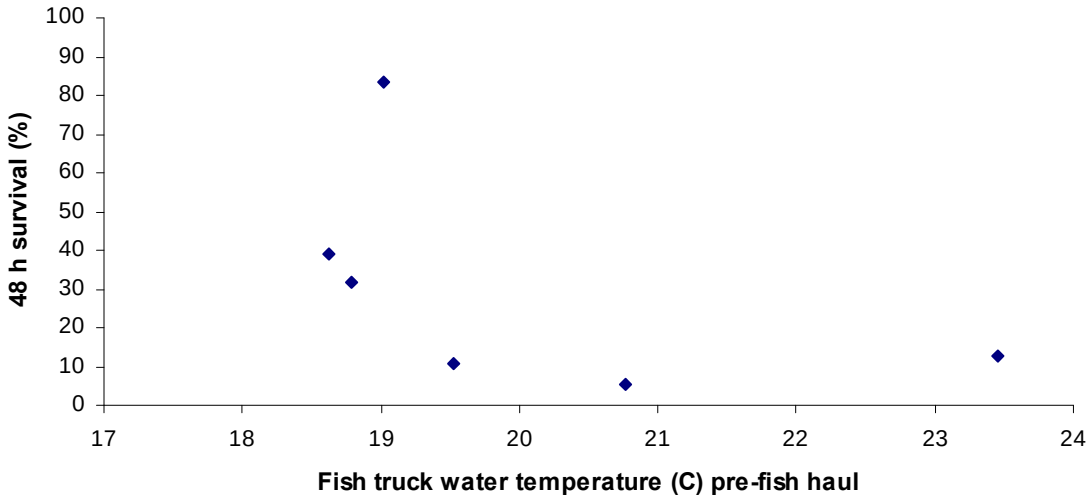

Figure 14 **Scatter plot for 48 h juvenile CHTR survival and pre-fish haul fish truck water temperature in 2005**

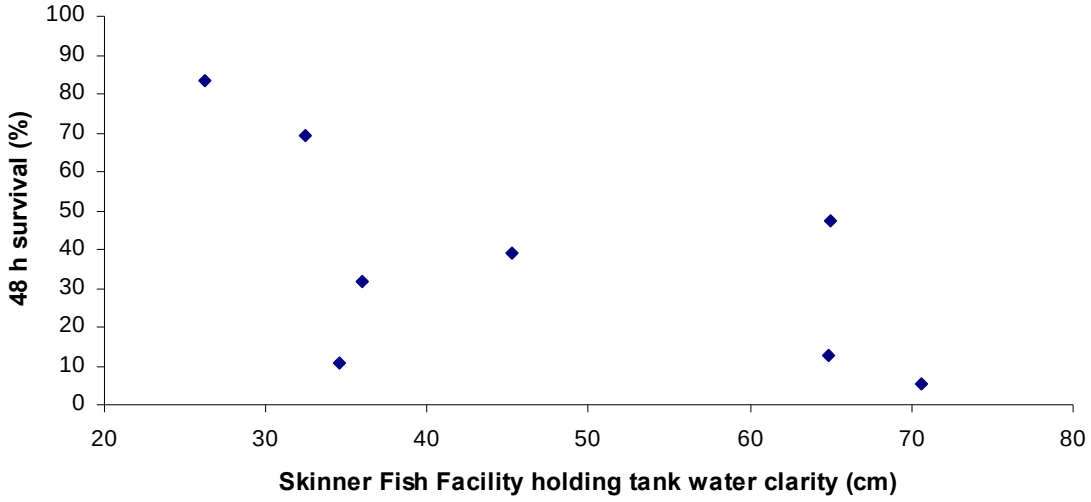

Figure 15 **Scatter plot for 48 h juvenile CHTR survival and Skinner Fish Facility holding tank water clarity in 2005**

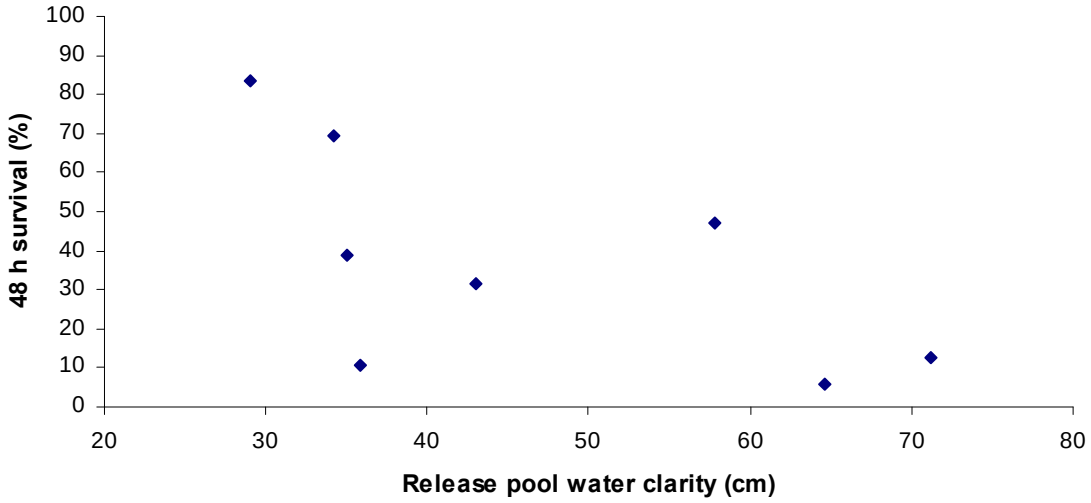

Figure 16 **Scatter plot for 48 h juvenile CHTR survival and release pool water clarity in 2005**

Fin injuries were common in 2005 (Table 10), and included fraying, tearing, and splitting. These fin injuries were also observed in many of the fish from the QC and control groups that were not exposed to the treatments. The mean percentage of fish injured did not significantly differ among the QC, control, CH, and CHTR groups (Kruskal-Wallis test: $H = 0.383$, $df = 3$, $p = 0.994$).

Table 10 Mean percent injury by type for juvenile delta smelt exposed to the CH and CHTR treatments in 2005 and 2006. The Kruskal-Wallis test was used to compare the percentages of fish injured in the QC, control, and treatment groups in 2005 and 2006 ($p < 0.05$).

Year	Group	Fish (n)	Percent injured by injury type				Percent of fish injured	p-value
			Head	Eyes	Skin	Fins		
2005	QC	84	0.0	0.0	0.0	21.4	21.4	0.994
	Control	126	0.8	0.0	0.0	13.5	14.3	
	CH	78	0.0	0.0	0.0	26.9	26.9	
	CHTR	38	0.0	0.0	0.0	21.1	25.0	
2006	QC	93	0.0	0.0	1.1	17.2	17.0	0.638
	Control	138	0.0	0.0	0.7	10.9	11.6	
	CH	96	0.0	0.0	0.0	14.6	14.6	
	CHTR	41	0.0	0.0	0.0	19.5	19.5	

In 2006, the mean recovery rate of 86.6% was very similar to the 86.2% recovery rate in the 2005 CH trials. The mean recovery rate of 88.8% in the 2006 CHTR trials was somewhat higher than in 2005 (Table 7). Similar to 2005, mean recovery rates increased with size (FL mm) of fish for each treatment. Mean survival rates at 48 h were 50.9% for the CH trials and 57.9% for the CHTR trials. A significant difference was detected for survival at 48 h among the control and treatment groups (Kruskal-Wallis test: $H = 21.03$, $df = 2$, $p = 0.000$). Multiple comparison testing revealed that the survivals at 48 h were significantly different between the control and the CH groups and also between the control and CHTR groups (Table 11). The CH and CHTR groups did not significantly differ.

Table 11 Nonparametric multiple comparisons for the 2006 juvenile survivals at 48 h of control, CH, and CHTR groups. Significant values, $p < 0.05$, are indicated with an asterisk.

Comparison	Difference Between Mean Ranks	Standard Error (SE)	Q
Control vs. CH	14.99	4.29	3.49*
Control vs. CHTR	18.74	5.56	3.37*
CH vs. CHTR	3.75	5.87	0.64

Significant moderate and positive relationships were detected between 48 h CH survival and water clarity in the UCD FCCL and Skinner Fish Facility holding tanks, whereas, significant moderate and negative relationships were detected between 48 h CHTR survival and Skinner Fish Facility dissolved oxygen, fish truck pre-fish haul, and release pool dissolved oxygen (Table 12). The majority of relationships between 48 h survival and environmental variables were counterintuitive including each of the significant relationships. Only weak and non-significant relationships were observed when 48 h CH survival was plotted against number of miscellaneous fish in the Skinner Fish Facility holding tank (Figure 17) and 48 h CHTR survival was plotted against release pool water clarity (Figure 18).

Table 12 Spearman rank correlation r_s values for 2006 juvenile CH and CHTR trials. Significant values, p <0.05, are indicated with an asterisk.

	Trial	n	Survival		
			0 h	24 h	48 h
Skinner Fish Facility water temp.	CH	15	0.224	0.203	0.206
Skinner Fish Facility DO	CH	15	0.058	-0.335	-0.341
Debris	CH	15	0.176	0.030	0.025
Misc. fish	CH	15	-0.299	-0.387	-0.418
FCCL holding tank secchi	CH	15	0.363	0.627	0.587 *
Skinner Fish Facility holding tank secchi	CH	15	0.427	0.615	0.646*
Skinner Fish Facility water temp.	CHTR	7	0.468	0.536	0.536
Skinner Fish Facility DO	CHTR	7	-0.829	-0.857	-0.964*
Fish truck water temp. (pre-fish haul)	CHTR	7	0.613	0.679	0.464
Fish truck DO (pre-fish haul)	CHTR	7	-0.739	-0.714	-0.857*
Fish truck water temp. (post-fish haul)	CHTR	7	0.613	0.679	0.464
Fish truck DO (post-fish haul)	CHTR	7	-0.487	-0.429	-0.607
Release pool water temp.	CHTR	7	0.378	0.464	0.429
Release pool DO	CHTR	7	-0.883	-0.893	-1.000*
Debris	CHTR	7	-0.135	-0.134	-0.401
Misc. fish	CHTR	7	-0.450	-0.429	-0.393
FCCL holding tank secchi	CHTR	7	0.378	0.464	0.500
Skinner Fish Facility holding tank secchi	CHTR	7	0.108	0.214	0.036
Release pool secchi	CHTR	7	-0.234	-0.143	-0.250

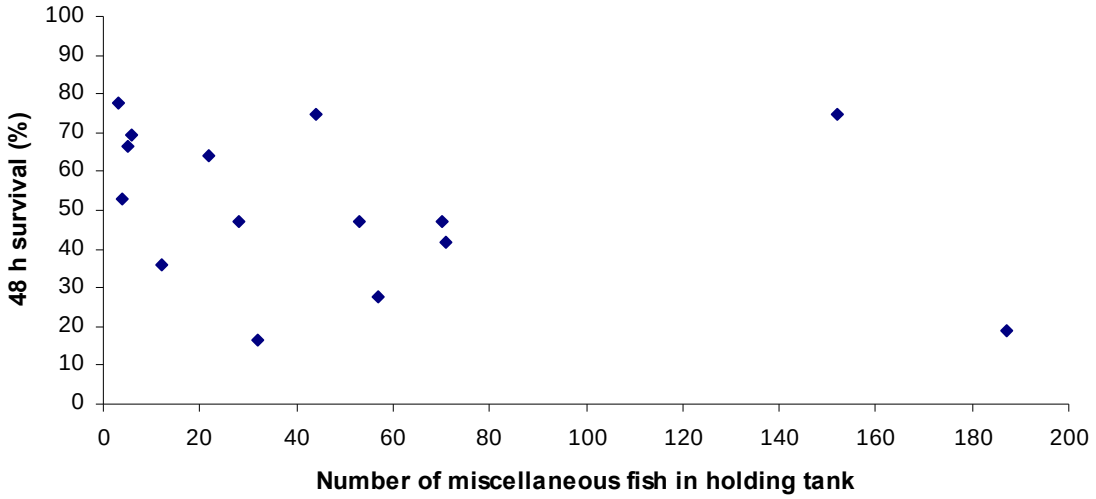

Figure 17 **Scatter plot for 48 h juvenile CH survival and the number of miscellaneous fish in the Skinner Fish Facility holding tank in 2006**

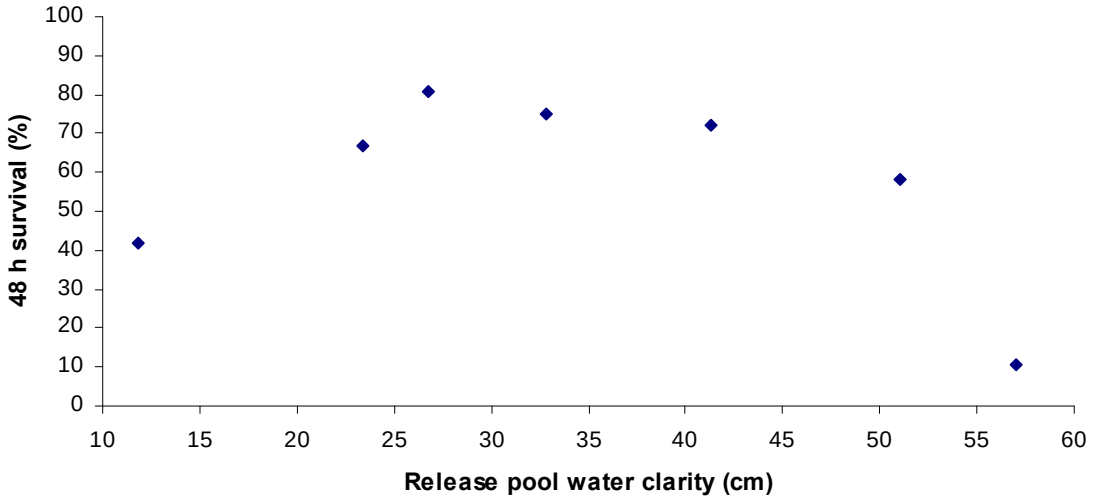

Figure 18 **Scatter plot for 48 h juvenile CHTR survival and release pool water clarity in 2006**

Similar to 2005, fin injuries were common in the 2006 trials (Table 10), and included fraying, tearing, and splitting. These fin injuries were also observed in many of the fish from the QC and control groups that were not exposed to the treatments. The percentages of fish injured did not significantly differ among the QC, control, CH, and CHTR groups (Kruskal-Wallis test: $H = 1.69$, $df = 3$, $p = 0.638$).

Wild Juvenile Delta Smelt and Predation

No wild juveniles were salvaged at the Skinner Fish Facility in 2006. Most of the wild juvenile delta smelt observed during the Department of Fish and Game's (DFG) 20 mm and townet surveys were in the Sacramento River and outside of the western Delta towards Suisun Bay (IEP 2007). Unlike the adult delta smelt trials, the stomachs of predatory fish were not checked for consumed test fish during the juvenile trials in 2006.

Juvenile Delta Smelt Holding Tank Efficiency Tests

Recoveries during the 2004 efficiency tests ranged from 40 to 94% (Table 13). Mean recovery rates tended to increase with increasing fish size for tests conducted in the 2 holding tank buildings. The greater than 35 mm FL group in the old holding tank building was the only exception, likely due to the small sample size.

Table 13 Mean percent recovery of juvenile delta smelt during holding tank efficiency tests at the Skinner Fish Facility in 2004

Size (FL)	New holding tank building				Old holding tank building			
	Trials (n)	Mean recovery (%)	SD	Range (%)	Trials (n)	Mean recovery (%)	SD	Range (%)
< 30 mm	4	56	8.16	50 - 68	5	62	19.42	40 - 90
30 to 35 mm	3	73	4.16	68 - 76	7	73	11.13	58 - 90
>35 mm	5	86	5.83	80 - 94	2	71	7.07	66 - 76

Quality Control

Water Quality

Duplicate water temperature measurements had the lowest mean percent deviation (0.59%) among the water quality measurements (Appendix Z). The mean percent deviation for specific conductivity, dissolved oxygen, and water clarity measurements, however, were considerably higher at 2.19, 3.60, and 3.12% respectively. The dissolved oxygen and water clarity measurements exceeded 5% deviation on 11 and 10 occasions respectively. The high number of dissolved oxygen measurements exceeding 5% deviation was for the most part due to differences in readings within the lower dissolved oxygen ranges (between 6 and 8 mg/L). The high number of water clarity measurements exceeding 5% was most likely due to the operator's ability to control the release valve on the Secchi tube used to measure water clarity.

Fish Measurements

The precision of fork length measurements during the 2005 and 2006 adult and juvenile CH and CHTR trials were within acceptable limits (Appendix Z). The mean percent deviation was 0.28% and only one measurement exceeded the 5% deviation. The precision of weight measurements for adult and juvenile fish in 2005 and 2006 had a slightly higher mean percent deviation (0.49%). A total of 4 weight measurements exceeded the 5% deviation. All 4 deviations beyond 5% were from juvenile fish whose weights were less than 0.5 grams.

Data Entry

Approximately 10 % of each adult and juvenile database for 2005 and 2006 was randomly checked against original data sheets. Five data entry errors were found and corrected. The error rate was less than 1% for all databases combined.

Discussion

Adult delta smelt survived the full CHTR process at the Skinner Fish Facility plus 48 hours at high rates. Conditions at the Skinner Fish Facility in winter (when adult delta smelt are usually salvaged) are considered more conducive to survival than those later in spring. Water temperatures never reach the higher thermal maxima of 25.4ºC for adults (Swanson and others 1999) and the numbers of incidental fish in the holding tanks are typically lower during the normal adult entrainment period at the facility. Baskerville-Bridges and others (2004) experienced higher survival (50-90%) when collecting wild sub-adult delta smelt from the Delta when water temperatures were ≤12ºC, which was similar to the trend for survival observed in the 2006 adult trials. Conversely, other conditions such as higher debris loads and a more than average number of predatory fish in the salvage holding tanks can potentially reduce the survival of adult delta smelt. The post-treatment survival in the 2005 CH and CHTR treatment groups were only influenced by handling and operational effects, while the 2006 CH and CHTR groups were exposed to the additional impacts of incidental fish and debris.

The survival rate of adult delta smelt observed in this study (85 to 93%) was lower than survival observed in some research studies on adult delta smelt, yet comparable in survival to other studies. Unlike this study, the other studies exposed adult delta smelt to only parts of the CHTR

process or to new methods of fish salvage. Miranda and others (2008) observed 95.2 to 98.7% survival of adult delta smelt released through a replicate of the SWP's Horseshoe Bend release site. Helfrich and others (2000) observed 99% immediate survival of adult delta smelt passed through a Hidrostal pump at the TFCF. Helfrich and others (2003) again observed high immediate survival (99 to 100%) and 96 h post treatment survival (86.4 to 89.8%) of sub-adult and adult delta smelt passed through a Hidrostal pump at the TFCF. Morinaka (2005) observed a mean survival of 90% for wild delta smelt during a pilot handling and trucking study at the Skinner Fish Facility, but not every trial exposed the delta smelt to a simulated fish release.

Although predation was not the primary focus of this study, the low rate of predation observed in the 2006 adult trials was similar to low predation rates observed in predation and diet studies of predatory fish conducted within the CHTR process in 2005 and 2006 (Geir Aasen, personal communication, 2008). Total daily fish salvage is typically lower during the winter and early spring months than later in the summer at the Skinner Fish Facility. Introducing cultured adult delta smelt into a holding tank with predatory fish but few prey fish may have affected the survival rates of adult delta smelt during those trials where predation was observed.

Juvenile delta smelt were found to survive the CHTR process at the Skinner Fish Facility at considerably lower rates than adults. Mean survival rates 48 h after treatment for this study averaged between 37 and 61% for all treatment groups, which was higher than the 19 and 48% mean survival rates observed for wild delta smelt during the handling and trucking study conducted at the Skinner Fish Facility in 2000 (Foss 2002b). Other handling and trucking studies conducted at the Skinner Fish Facility resulted in much lower survival rates for wild juvenile delta smelt, ranging from 11 to 17% after 24 hours post treatment during the1984-85 study (Foss 2002a) to 0 to 3% survival after 48 hours post-treatment during the 2000 study (Afentoulis 2002).

Conditions, particularly water temperatures and fish crowding, were probably less conducive to survival when juvenile delta smelt were salvaged at the Skinner Fish Facility. Water temperatures ranged between 18 and 24°C during this study's trials, and were normal for the seasonal (reference) period, but at the upper end approaching the thermal tolerance of delta smelt (Swanson and others 1999). Temperature studies conducted at the UCD FCCL showed that higher mortalities occurred when juvenile delta smelt (22 mm FL) were reared in 23°C water versus at 17°C and 20°C (Baskerville-Bridges and others 2004). In 1998, laboratory experiments at UCD measured the upper temperature tolerance limit (point when fish lose equilibrium) for delta smelt (3.8-4.7 cm standard length) and found that to be 25.4°C (Swanson and others 1999). In the 1984 and 1985 DFG handling and trucking evaluations, the Skinner holding tank water temperatures were significantly and positively correlated to striped bass mortality in the handling tests, and water temperatures in the fish truck were significantly and positively correlated to mortality in the trucking test (Raquel 1989). Raquel found that smaller fish size combined with water temperatures exceeding 21.1°C were two factors that lead to lower survival rates for striped bass.

The annual recruitment of juvenile fishes combined with the warmer water temperatures associated with late spring can result in crowded conditions and lower dissolved oxygen levels in the Skinner Fish Facility holding tanks, loading buckets, and fish truck tanks. Skinner holding tank temperatures, holding tank dissolved oxygen levels, and truck dissolved oxygen levels were significantly correlated with mortality in striped bass, threadfin shad, and white catfish during the DFG handling and trucking evaluations in 1984 and 1985 (Raquel 1989). These factors associated with fish salvage and the addition of experimental handling may have contributed to the acute mortality observed in the juvenile trials.

The substantial delayed mortality of control fish in addition to the treatment fish during juvenile experiments, suggests that other stressors, such as pre- and post-trial handling or poor initial health, may have contributed to decreased juvenile survival. The UCD FCCL reduces the holding tank water temperature to 15°C before handling and transporting juvenile delta smelt (Bradd Baskerville-Bridges, personal communication, 2008). Juvenile delta smelt were handled and transported at much higher temperatures throughout the course of this study. High mortality (up to 70%) attributed to higher water temperatures and handling, was also observed while marking juvenile delta smelt with calcein at the FCCL in 2008 (Castillo 2008). There may be an important temperature threshold for juvenile delta smelt survival between 15 and 18 °C, because Castillo (2008) observed high survival when marking juveniles in 15°C water, but high mortalities were observed when marking in 18°C water. Differences in water temperatures between the UCD FCCL holding tanks where the juvenile delta smelt were held prior to the CH and CHTR trials and the Skinner Fish Facility holding tanks may have influenced juvenile survival in 2005 and 2006 (Appendix C and G). On numerous occasions, juvenile delta smelt had to be acclimated within an hour before being injected into the holding tanks at the Skinner Fish Facility. Average difference in water temperature between the holding tanks at the FCCL and Skinner Fish Facility was 2.8°C for both 2005 and 2006, and fish were typically transferred into 18-22°C water, a temperature range where juvenile delta smelt survived poorly in other studies (e.g., Castillo 2008).

Environmental factors did not appear to have a strong influence on delta smelt survival during each life stage, however, the small sample sizes during the CH and CHTR trials may have affected the outcome. The sample sizes for the 2005 adult CH and CHTR trials were too small to observe any significant relationships. On the other hand, several environmental factors (i.e., water temperature and DO) were significantly correlated to adult delta smelt survival during the 2006 CH and CHTR trials. Although no significant relationships were observed in the 2005 juvenile trials, water temperature and water clarity showed moderate relationships with survival. Whereas, several environmental factors (i.e. water clarity and DO) during the 2006 juvenile trials were significantly correlated to survival, but were counterintuitive.

The results suggest that the full CHTR process did not appreciably decrease survival beyond that suffered from the CH treatment. The small difference in mean survivals may suggest actual differences in mortality, but the number of trials may have been too low to demonstrate statistical differences. Survival results indicated cumulative impacts throughout the CHTR process and suggest that the CH effects may be the dominant factor in the overall CHTR process. Similar cumulative impacts were observed in cortisol response for adult delta smelt exposed to the CHTR process (Afentoulis 2008). Neither adult delta smelt injury rates nor juvenile delta smelt injury

rates differed significantly between the CH and CHTR treatments. Scale loss observed on cultured adult delta smelt was very minimal during the CH and CHTR treatments compared to other fish species like shad which lose a high percentage of scales.

This study predominantly focused on the condition and survival of adult and juvenile delta smelt after they have been exposed to the CHTR process. Study observations indicate that other losses occurred during the CHTR process, particularly during the draining process when salvaged fish were removed from the Skinner Fish Facility holding tanks. During this process, the loading bucket was seated at the bottom of the holding tank before water and fish from the tank were flushed into the bucket. Apparently, fish from the tank can be lost down the drain through a small gap between the lip of the bucket and the holding tank when the bucket is seated, and during the 2004 efficiency experiment, loss was inversely related to fish size for juvenile fish. Juvenile delta smelt are more vulnerable to being lost down the drain than adults during this process because of their relatively smaller size, and we attribute the lower recovery rates of our injected juvenile fish to this factor. The relatively high loss rates (14-44%) observed in the 2004 holding tank efficiency tests suggest that current screening and drain design of the holding tanks were major contributors to the loss of smaller juvenile delta smelt.

Although only 29 wild adult delta smelt were collected during the course of this study, the 9 recovered after the full CHTR element all survived for 48 hours following treatment. The survival of wild adult delta smelt was higher than the survival of cultured adult delta smelt after being exposed to the CHTR process. The percentages of injured fish did not differ between the wild delta smelt and the cultured delta smelt, but the mean percent scale loss was higher for wild fish. Less can be said about the similarity of fish injuries on cultured adults and wild adults because unlike the cultured adults, the wild adults may have sustained injuries prior to being exposed to the CHTR process. The survival rates of wild juvenile delta smelt could not be compared with the survival rates of cultured juveniles, because no wild juveniles were salvaged in 2006.

Recommendations

This was the first study focusing on the survival and injury of adult and juvenile delta smelt exposed to the CHTR process. Findings from this study indicate that delta smelt recovered at the end of the CHTR process can survive at relatively high rates, but losses occur during and shortly after the CHTR process.

Predation was observed in the adult CH and CHTR trials conducted in 2006. Methods to prevent the accumulation of predators within the salvage holding tanks would not only increase the survival of delta smelt, but the survival of other prey fishes as well. Two strategies to reduce the predation of fish in the holding tanks and during the CHTR process are: 1) more-frequent removal of predators by flushing the secondary channels preceding the salvage holding tanks, and 2) employing methods to sort large salvaged fish from small salvaged fish before filling the holding tanks. Loss of juvenile delta smelt to predation was not observed during this study; however, losses resulting from equipment limitations were observed.

Improvements to the existing salvage holding tanks can help reduce the loss of small fish. The 2004 holding tank efficiency tests showed that small fish (≤35mm) could be lost at high rates

(>25%) and that these losses apparently occurred at the gaps between the holding tank bottom and the collection bucket. During this study, the concrete bottoms of the salvage holding tanks were rough and pitted, which prevented a smooth transition from the holding tank to the loading bucket during fish removal. Smoothing the bottom of the holding tanks (e.g., with an epoxy filler) might increase the number of fish that make it into the bucket from the holding tank. Following this study, DWR blasted and coated the bottoms of each holding tank to provide the smooth transition from the holding tank into the loading bucket. As mentioned earlier, smaller fish can also be lost down the drain when fish are being removed from the salvage holding tanks. If it is not be feasible to reduce the gap when the loading bucket is seated on the bottom of the holding tank, increasing the slope at this transition point may reduce loss of fish down the drain.

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Appendixes

Appendix A: Water temperature and dissolved oxygen measurements for the 2005 adult CH and CHTR trials

Treatment	Date	UCD FCCL water temp. (°C)	Skinner Facility water temp. (°C)	Fish truck pre-haul water temp. (°C)	Fish truck post-haul water temp. (°C)	Release pool water temp. (°C)	UCD FCCL dissolved oxygen (mg/L)	Skinner Facility dissolved oxygen (mg/L)	Fish truck pre-haul dissolved oxygen (mg/L)	Fish truck post-haul dissolved oxygen (mg/L)	Release pool dissolved oxygen (mg/L)
CH	4/06/05	---	14.65	---	---	---	---	9.34	---	---	---
CH	4/12/05	13.53	14.46	---	---	---	9.93	9.48	---	---	---
CH	4/20/05	13.20	14.93	---	---	---	10.19	9.16	---	---	---
CH	4/20/05	13.22	14.96	---	---	---	6.27	8.45	---	---	---
CH	4/25/05	13.71	15.89	---	---	---	11.25	8.44	---	---	---
CH	4/27/05	13.75	16.80	---	---	---	10.98	9.31	---	---	---
CHTR	4/11/05	---	14.71	---	15.47	15.46	---	9.60	---	10.69	10.36
CHTR	4/12/05	12.94	14.40	14.59	---	14.72	9.43	9.14	9.64	0.00	8.82
CHTR	4/18/05	13.23	16.11	---	16.04	16.10	8.80	8.77	---	10.75	7.24
CHTR	4/25/05	13.31	16.06	16.15	16.46	15.90	10.25	8.12	9.35	10.50	8.92

Appendix B: **Water clarity and specific conductivity measurements for the 2005 adult CH and CHTR trials**

Treatment	Start Date	Skinner Facility Water clarity (cm)	Release pool Water clarity (cm)	UCD FCCL Specific conductivity (µS/cm)	Skinner Facility Specific conductivity (µS/cm)	Fish truck pre-haul Specific conductivity (µS/cm)	Fish truck post-haul Specific conductivity (µS/cm)	Release pool Specific conductivity (µS/cm)
CH	4/06/05	78.2	---	---	222	---	---	---
CH	4/12/05	70.2	---	601	289	---	---	---
CH	4/20/05	48.0	---	482	275	---	---	---
CH	4/20/05	54.2	---	480	273	---	---	---
CH	4/25/05	100.0	---	1096	290	---	---	---
CH	4/27/05	74.0	---	828	288	---	---	---
CHTR	4/11/05	100.1	---	---	271	---	6494	1741
CHTR	4/12/05	69.2	58.9	602	285	525	---	298
CHTR	4/18/05	67.0	70.8	501	306	---	4619	300
CHTR	4/25/05	88.8	122.0	1125	275	7004	5493	270

Appendix C: **Water temperature and dissolved oxygen measurements for the 2005 juvenile CH and CHTR trials**

Treatment	Date	UCD FCCL water temp. (°C)	Skinner Facility water temp. (°C)	Fish truck pre-haul water temp. (°C)	Fish truck post-haul water temp. (°C)	Release pool water temp. (°C)	UCD FCCL dissolved oxygen (mg/L)	Skinner Facility dissolved oxygen (mg/L)	Fish truck pre-haul dissolved oxygen (mg/L)	Fish truck post-haul dissolved oxygen (mg/L)	Release pool dissolved oxygen (mg/L)
CH	5/16/05	13.92	19.82	---	---	---	9.45	8.45	---	---	---
CH	5/17/05	13.95	18.48	---	---	---	10.70	8.68	---	---	---
CH	5/24/05	15.76	20.12	---	---	---	9.47	7.28	---	---	---
CH	6/06/05	17.40	18.45	---	---	---	8.51	8.09	---	---	---
CH	6/07/05	17.32	17.73	---	---	---	8.38	8.01	---	---	---
CH	6/08/05	16.92	18.25	---	---	---	8.84	7.41	---	---	---
CH	6/13/05	19.27	22.34	---	---	---	9.86	8.65	---	---	---
CH	6/14/05	18.85	21.95	---	---	---	8.41	6.72	---	---	---
CH	6/15/05	18.80	20.90	---	---	---	8.18	6.74	---	---	---
CH	6/28/05	21.19	20.45	---	---	---	7.19	6.97	---	---	---
CH	6/28/05	22.67	21.05	---	---	---	6.13	7.72	---	---	---
CH	7/11/05	22.96	22.81	---	---	---	7.20	7.25	---	---	---
CH	7/11/05	23.59	22.98	---	---	---	7.45	6.21	---	---	---
CHTR	5/18/05	14.06	18.29	18.79	19.12	18.43	9.81	8.06	7.36	10.34	7.44
CHTR	5/23/05	14.11	19.34	19.52	19.98	19.88	9.83	7.87	6.51	10.26	8.00
CHTR	5/31/05	17.16	18.87	---	21.50	21.02	10.09	8.56	---	12.30	7.19
CHTR	6/06/05	17.04	17.54	19.02	18.99	18.58	7.57	7.90	7.32	9.96	7.57
CHTR	6/07/05	16.87	17.63	18.62	18.57	18.67	9.50	8.25	8.47	10.75	8.10
CHTR	6/13/05	17.79	21.35	20.77	21.63	22.47	8.75	6.57	6.86	13.15	7.62
CHTR	7/05/05	23.44	22.87	---	23.90	23.82	7.04	6.44	---	8.82	7.72
CHTR	7/12/05	24.36	24.12	23.45	24.24	24.69	7.42	6.05	8.20	9.73	6.88

Appendix D: **Water clarity and specific conductivity measurements for the 2005 juvenile CH and CHTR trials**

Treatment	Start Date	Skinner Facility Water clarity (cm)	Release pool Water clarity (cm)	UCD FCCL Specific conductivity (µS/cm)	Skinner Facility Specific conductivity (µS/cm)	Fish truck pre-haul Specific conductivity (µS/cm)	Fish truck post-haul Specific conductivity (µS/cm)	Release pool Specific conductivity (µS/cm)
CH	5/16/05	69.8	---	345	243	---	---	---
CH	5/17/05	41.6	---	359	221	---	---	---
CH	5/24/05	51.1	---	164	181	---	---	---
CH	6/06/05	26.2	---	120	127	---	---	---
CH	6/07/05	49.0	---	128	145	---	---	---
CH	6/08/05	63.8	---	136	146	---	---	---
CH	6/13/05	93.0	---	183	192	---	---	---
CH	6/14/05	63.8	---	181	188	---	---	---
CH	6/15/05	39.4	---	180	183	---	---	---
CH	6/28/05	32.2	---	192	186	---	---	---
CH	6/28/05	33.4	---	195	190	---	---	---
CH	7/11/05	43.8	---	211	201	---	---	---
CH	7/11/05	57.0	---	207	200	---	---	---
CHTR	5/18/05	36.0	43.0	366	221	4794	5646	223
CHTR	5/23/05	34.6	35.8	446	197	7681	5722	797
CHTR	5/31/05	65.0	57.8	113	116	---	6097	122
CHTR	6/06/05	26.2	29.0	117	126	8157	6033	134
CHTR	6/07/05	45.2	35.0	122	143	4370	5228	152
CHTR	6/13/05	70.6	64.6	181	186	7735	5972	192
CHTR	7/05/05	32.5	34.2	1135	214	---	6289	205
CHTR	7/12/05	64.8	71.2	210	217	10471	11635	208

Appendix E: **Water temperature and dissolved oxygen measurements for the 2006 adult CH and CHTR trials**

Treatment	Date	UCD FCCL water temp. (°C)	Skinner Facility water temp. (°C)	Fish truck pre-haul water temp. (°C)	Fish truck post-haul water temp. (°C)	Release pool water temp. (°C)	UCD FCCL dissolved oxygen (mg/L)	Skinner Facility dissolved oxygen (mg/L)	Fish truck pre-haul dissolved oxygen (mg/L)	Fish truck post-haul dissolved oxygen (mg/L)	Release pool dissolved oxygen (mg/L)
CH	12/20/05	11.84	10.10	---	---	---	10.85	10.26	---	---	---
CH	12/21/05	11.70	10.80	---	---	---	9.90	9.57	---	---	---
CH	1/03/06	9.99	10.77	---	---	---	10.92	9.69	---	---	---
CH	1/04/06	10.07	10.76	---	---	---	11.62	9.78	---	---	---
CH	1/10/06	10.51	10.65	---	---	---	10.96	8.92	---	---	---
CH	1/11/06	10.57	10.90	---	---	---	10.91	8.93	---	---	---
CH	1/17/06	9.74	9.98	---	---	---	12.49	10.71	---	---	---
CH	1/17/06	10.67	10.20	---	---	---	10.70	10.80	---	---	---
CH	1/18/06	10.57	10.30	---	---	---	11.47	10.13	---	---	---
CH	1/23/06	9.86	9.63	---	---	---	11.25	10.53	---	---	---
CH	1/23/06	10.51	9.91	---	---	---	10.58	9.20	---	---	---
CH	1/24/06	9.64	9.63	---	---	---	11.62	10.08	---	---	---
CH	1/30/06	10.47	11.04	---	---	---	10.32	9.51	---	---	---
CH	2/21/06	10.14	10.38	---	---	---	10.21	9.29	---	---	---
CH	2/22/06	10.24	10.51	---	---	---	10.22	9.86	---	---	---
CH	2/22/06	10.24	---	---	---	---	10.22	---	---	---	---
CH	3/07/06	10.62	11.76	---	---	---	9.56	9.67	---	---	---
CH	3/08/06	10.27	11.09	---	---	---	9.63	8.93	---	---	---
CH	3/13/06	10.04	10.41	---	---	---	9.68	9.05	---	---	---
CH	3/14/06	10.30	11.24	---	---	---	11.11	10.56	---	---	---
CH	3/14/06	10.30	11.24	---	---	---	11.11	11.00	---	---	---
CH	3/20/06	10.84	11.71	---	---	---	9.60	9.48	---	---	---
CH	3/20/06	10.84	11.71	---	---	---	9.60	9.60	---	---	---
CH	3/21/06	10.13	11.07	---	---	---	10.40	9.21	---	---	---

Appendix E: (continued)

Treatment	Date	UCD FCCL water temp. (°C)	Skinner Facility water temp. (°C)	Fish truck pre-haul water temp. (°C)	Fish truck post-haul water temp. (°C)	Release pool water temp. (°C)	UCD FCCL dissolved oxygen (mg/L)	Skinner Facility dissolved oxygen (mg/L)	Fish truck pre-haul dissolved oxygen (mg/L)	Fish truck post-haul dissolved oxygen (mg/L)	Release pool dissolved oxygen (mg/L)
CH	3/21/06	10.13	10.99	---	---	---	10.40	9.77	---	---	---
CH	3/27/06	12.06	13.16	---	---	---	9.40	9.33	---	---	---
CH	3/27/06	12.06	13.28	---	---	---	9.40	9.20	---	---	---
CH	4/04/06	12.56	13.26	---	---	---	9.22	8.95	---	---	---
CH	4/10/06	13.89	14.79	---	---	---	9.92	8.98	---	---	---
CH	4/11/06	13.35	14.66	---	---	---	9.88	8.23	---	---	---
CH	4/18/06	12.43	14.69	---	---	---	9.30	8.08	---	---	---
CH	4/24/06	13.91	15.51	---	---	---	9.72	9.45	---	---	---
CHTR	1/31/06	10.45	10.52	11.54	10.81	10.39	10.10	9.90	9.78	13.55	10.60
CHTR	2/01/06	10.57	10.81	11.24	11.10	10.77	9.81	9.62	10.83	13.51	10.40
CHTR	2/06/06	10.95	11.04	11.59	10.85	11.12	9.10	8.77	11.22	13.09	9.87
CHTR	2/07/06	10.33	11.21	11.65	11.06	10.84	9.86	9.25	10.90	12.52	8.78
CHTR	2/08/06	10.45	11.49	11.75	11.07	11.26	12.05	10.09	12.60	13.25	10.96
CHTR	2/14/06	11.80	12.68	12.91	12.45	12.51	9.77	8.58	10.80	12.39	9.73
CHTR	2/15/06	10.60	11.73	11.88	11.30	11.70	8.93	8.89	9.70	11.76	9.15
CHTR	3/22/06	10.09	11.42	12.03	11.75	11.41	10.97	10.76	11.15	12.45	10.40
CHTR	3/28/06	12.47	13.18	13.41	13.27	13.10	10.40	9.41	10.10	13.15	9.71
CHTR	4/19/06	12.62	15.37	15.74	15.62	15.58	10.84	9.25	8.91	11.67	8.86
CHTR	4/25/06	14.81	15.86	---	15.49	15.88	9.74	9.31	---	12.33	9.26
CHTR	5/02/06	16.37	19.05	18.92	18.71	19.10	9.42	7.88	8.75	10.73	8.21
CHTR	5/03/06	16.33	18.61	18.75	18.35	18.70	9.14	7.90	9.36	10.46	8.23

Appendix F: **Water clarity, specific conductivity, debris, and total miscellaneous fish for the 2006 adult CH and CHTR trials**

Treatment	Start Date	UCD FCCL water clarity (cm)	Skinner Facility water clarity (cm)	Release pool water clarity (cm)	UCD FCCL specific conductivity (µS/cm)	Skinner Facility specific conductivity (µS/cm)	Fish truck pre-haul specific conductivity (µS/cm)	Fish truck post-haul specific conductivity (µS/cm)	Release pool specific conductivity (µS/cm)	Debris (kg)	Total misc. fish
CH	12/20/05	79.0	86.2	---	422	404	---	---	---	12.1	14
CH	12/21/05	60.0	60.0	---	478	458	---	---	---	2.5	18
CH	1/03/06	44.0	48.6	---	235	238	---	---	---	3.6	37
CH	1/04/06	74.4	53.4	---	240	228	---	---	---	1.8	28
CH	1/10/06	57.0	57.0	---	125	117	---	---	---	4.3	18
CH	1/11/06	57.0	55.9	---	124	119	---	---	---	1.5	19
CH	1/17/06	52.6	61.0	---	136	136	---	---	---	0.0	2
CH	1/17/06	75.0	70.6	---	140	138	---	---	---	3.3	18
CH	1/18/06	64.6	55.8	---	142	150	---	---	---	1.1	11
CH	1/23/06	68.4	52.0	---	171	169	---	---	---	0.9	5
CH	1/23/06	56.6	64.8	---	174	165	---	---	---	1.9	6
CH	1/24/06	59.6	79.3	---	188	181	---	---	---	0.6	4
CH	1/29/06	110.0	92.0	---	208	216	---	---	---	4.0	7
CH	2/20/06	80.3	96.5	---	191	193	---	---	---	3.6	143
CH	2/21/06	96.7	101.8	---	191	190	---	---	---	15.7	18
CH	2/21/06	96.7	---	---	191	---	---	---	---	14.1	20
CH	3/06/06	122.0	122.0	---	194	198	---	---	---	19.1	16
CH	3/07/06	122.0	122.0	---	176	162	---	---	---	14.1	15
CH	3/12/06	122.0	122.0	---	149	138	---	---	---	9.6	22
CH	3/13/06	122.0	122.0	---	146	142	---	---	---	5.9	8
CH	3/13/06	122.0	122.0	---	146	143	---	---	---	5.5	2
CH	3/20/06	122.0	122.0	---	148	151	---	---	---	2.7	13
CH	3/20/06	122.0	122.0	---	148	150	---	---	---	3.6	7

Appendix F: (continued)

Treatment	Start Date	UCD FCCL water clarity (cm)	Skinner Facility water clarity (cm)	Release pool water clarity (cm)	UCD FCCL specific conductivity (µS/cm)	Skinner Facility specific conductivity (µS/cm)	Fish truck pre-haul specific conductivity (µS/cm)	Fish truck post-haul specific conductivity (µS/cm)	Release pool specific conductivity (µS/cm)	Debris (kg)	Total misc. fish
CH	3/21/06	122.0	122.0	---	145	153	---	---	---	13.8	4
CH	3/27/06	67.0	58.2	---	169	175	---	---	---	4.6	29
CH	3/27/06	67.0	65.3	---	169	170	---	---	---	2.5	16
CH	4/03/06	96.1	94.6	---	133	135	---	---	---	0.0	213
CH	4/09/06	102.4	93.5	---	134	131	---	---	---	2.0	96
CH	4/11/06	105.8	---	---	132	132	---	---	---	3.3	188
CH	4/17/06	88.5	96.4	---	119	123	---	---	---	6.5	291
CH	4/23/06	122.0	87.5	---	105	109	---	---	---	4.6	46
CHTR	1/30/06	96.9	109.6	73.9	213	215	213	4028	4580	9.6	45
CHTR	1/31/06	122.0	110.8	101.2	217	220	218	4833	4088	32.4	110
CHTR	2/05/06	110.4	90.6	75.6	225	228	229	2933	4085	8.9	56
CHTR	2/06/06	103.2	107.1	70.2	221	226	221	4615	4859	8.5	53
CHTR	2/07/06	103.5	99.4	74.4	216	224	222	3420	3996	11.8	57
CHTR	2/13/06	97.9	94.7	72.8	219	227	225	3100	3605	34.8	24
CHTR	2/14/06	75.6	66.9	60.0	213	222	222	2302	3177	38.0	68
CHTR	3/21/06	122.0	122.0	122.0	156	167	169	3266	4906	4.6	7
CHTR	3/28/06	102.0	96.6	87.2	164	174	168	3135	3801	4.8	27
CHTR	4/18/06	104.6	104.0	87.6	121	127	132	4100	5296	1.5	228
CHTR	4/24/06	122.0	122.0	87.2	330	111	108	---	4923	16.4	54
CHTR	5/01/06	122.0	104.1	84.7	95	101	103	3840	4943	0.0	90
CHTR	5/02/06	102.3	109.1	79.7	98	103	102	4634	5312	3.9	30

Appendix G: **Water temperature and dissolved oxygen measurements for the 2006 juvenile CH and CHTR trials**

Treatment	Date	UCD FCCL water temp. (°C)	Skinner Facility water temp. (°C)	Fish truck pre-haul water temp. (°C)	Fish truck post-haul water temp. (°C)	Release pool water temp. (°C)	UCD FCCL dissolved oxygen (mg/L)	Skinner Facility dissolved oxygen (mg/L)	Fish truck pre-haul dissolved oxygen (mg/L)	Fish truck post-haul dissolved oxygen (mg/L)	Release pool dissolved oxygen (mg/L)
CH	6/12/06	17.90	18.84				8.88	8.05			
CH	6/13/06	18.40	18.80				8.64	6.58			
CH	6/14/06	18.39	18.80				8.23	7.94			
CH	6/18/06	17.87	20.15				8.58	7.53			
CH	6/20/06	19.57	20.79				8.78	8.09			
CH	6/26/06	20.58	23.95				8.53	6.48			
CH	6/27/06	19.84	23.66				8.67	6.72			
CH	6/28/06	19.30	23.48				8.92	7.36			
CH	6/28/06	19.66	23.62				8.64	7.18			
CH	7/03/06	19.34	22.45				8.20	5.84			
CH	7/05/06	17.88	21.66				8.41	6.88			
CH	7/05/06	18.02	21.63				8.28	7.06			
CH	7/10/06	19.42	24.35				8.59	6.87			
CH	7/11/06	22.01	23.29				7.10	7.17			
CH	7/12/06	19.75	21.55				8.43	7.84			
CHTR	6/05/06	16.88	20.46	20.36	20.35	20.74	9.25	7.94	9.16	11.60	8.53
CHTR	6/26/06	20.88	23.87	24.30	24.82	24.52	8.55	6.74	8.50	10.13	7.15
CHTR	6/27/06	19.92	23.62	24.65	25.54	24.39	8.77	6.67	7.62	10.00	6.93
CHTR	7/03/06	19.04	22.55	22.61	22.14	22.26	8.05	6.28	6.18	8.59	6.54
CHTR	7/10/06	19.14	24.37	24.27	24.04	24.41	8.54	6.31	6.88	9.61	6.77
CHTR	7/11/06	20.40	23.21	23.67	23.62	23.29	8.49	6.87	6.29	8.72	6.97
CHTR	7/12/06	20.19	21.81	22.34	21.91	21.45	8.55	7.40	8.08	8.88	7.18

Appendix H: **Water clarity, specific conductivity, debris, and total miscellaneous fish for the 2006 juvenile CH and CHTR trials**

Treatment	Start Date	UCD FCCL Water Clarity (cm)	Skinner Facility Water clarity (cm)	Release pool Water clarity (cm)	UCD FCCL Specific conductivity (µS/cm)	Skinner Facility Specific conductivity (µS/cm)	Fish truck pre-haul Specific conductivity (µS/cm)	Fish truck post-haul Specific conductivity (µS/cm)	Release pool Specific conductivity (µS/cm)	Debris (kg)	Total Misc. fish
CH	6/12/06	40.8	25.2		110	107				0.4	53
CH	6/13/06	48.2	39.4		100	100				2.2	152
CH	6/14/06	68.2	60.0		98	99				3.4	44
CH	6/18/06	12.2	15.0		141	99				0.0	187
CH	6/20/06	36.0	42.0		109	103				5.5	71
CH	6/26/06	52.2	45.0		135	130				0.0	3
CH	6/27/06	59.2	33.2		134	128				0.0	6
CH	6/28/06	75.1	40.4		124	120				0.0	28
CH	6/28/06	69.9	39.6		123	121				0.0	22
CH	7/03/06	53.2	32.8		130	148				0.0	12
CH	7/05/06	34.9	15.5		148	149				0.1	57
CH	7/05/06	22.1	12.5		147	147				1.3	70
CH	7/10/06	55.2	41.4		152	157				0.0	4
CH	7/11/06	36.8	25.2		154	167				0.3	5
CH	7/12/06	18.6	4.4		151	169				0.4	32
CHTR	6/05/06	55.5	38.2	57.0	606	112	3130	5421	109	2.0	2515
CHTR	6/26/06	62.1	48.6	51.0	132	132	4380	5490	133	0.0	56
CHTR	6/27/06	60.1	45.2	41.3	134	127	6332	6901	125	0.4	26
CHTR	7/03/06	59.6	31.8	26.8	130	145	5110	5659	142	0.0	123
CHTR	7/10/06	66.1	41.6	32.8	157	160	4392	5857	160	0.0	3
CHTR	7/11/06	50.2	33.2	23.4	146	160	1624	1910	162	0.0	8
CHTR	7/12/06	26.7	12.4	11.8	150	158	3508	5129	165	0.0	40

Appendix I: Post-treatment CHTR test fish building water temperature and dissolved oxygen measurements at 0, 24, and 48 h for the 2005 adult CH and CHTR trials

Treatment	Start date	0 h		24 h		48 h	
		Water temp. (°C)	Dissolved oxygen (mg/L)	Water temp. (°C)	Dissolved oxygen (mg/L)	Water temp. (°C)	Dissolved oxygen (mg/L)
CH	4/06/05	14.65	9.34	14.70	9.75	14.02	10.13
Control	4/06/05	14.81	10.23	14.67	9.36	13.96	10.06
CH	4/12/05	14.04	9.39	13.78	8.82	13.67	10.02
Control	4/12/05	14.22	9.87	13.84	8.90	13.77	10.40
CH	4/20/05	13.65	9.29	14.06	9.42	16.25	9.33
Control	4/20/05	14.04	9.69	14.16	9.30	16.49	7.98
CH	4/20/05	13.62	8.50	14.15	8.32	14.30	8.08
Control	4/20/05	13.56	7.08	13.91	9.28	14.58	7.74
CH	4/25/05	13.29	11.02	15.04	10.37	15.08	8.75
Control	4/25/05	13.32	10.23	15.00	9.49	15.20	9.62
CH	4/27/05	15.24	10.36	14.39	9.19	15.07	9.25
Control	4/27/05	15.15	10.80	14.38	8.61	14.78	9.93
CHTR	4/11/05	14.97	9.82	14.61	9.09	14.05	8.86
Control	4/11/05	14.55	10.37	14.52	9.93	14.40	8.65
CHTR	4/12/05	14.41	9.68	14.19	8.11	14.37	10.11
Control	4/12/05	14.20	9.64	14.22	8.79	14.47	10.58
CHTR	4/18/05	14.62	8.47	14.66	8.24	15.11	6.41
Control	4/18/05	14.49	9.71	14.42	8.88	14.21	7.00
CHTR	4/25/05	13.48	10.86	14.78	9.88	15.16	10.57
Control	4/25/05	13.24	10.14	14.73	9.33	15.23	10.50

Appendix J: Post-treatment CHTR test fish building water clarity and specific conductivity measurements at 0, 24, and 48 h for the 2005 adult CH and CHTR trials

Treatment	Start date	0 h		24 h		48 h	
		Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)
CH	4/06/05	78.2	222	93.8	226	93.3	242
Control	4/06/05	88.0	222	95.6	225	102.0	240
CH	4/12/05	84.6	305	122.0	293	122.0	269
Control	4/12/05	89.0	303	122.0	293	122.0	274
CH	4/20/05	69.8	262	122.0	264	98.0	274
Control	4/20/05	61.9	268	122.0	264	80.8	276
CH	4/20/05	59.9	262	122.0	265	122.0	261
Control	4/20/05	78.0	263	122.0	263	117.5	263
CH	4/25/05	122.0	253	122.0	262	122.0	263
Control	4/25/05	122.0	253	122.0	262	122.0	264
CH	4/27/05	122.0	263	122.0	256	122.0	262
Control	4/27/05	122.0	263	122.0	256	122.0	260
CHTR	4/11/05	122.0	337	122.0	299	122.0	293
Control	4/11/05	122.0	270	88.5	283	122.0	291
CHTR	4/12/05	122.0	294	122.0	290	122.0	296
Control	4/12/05	86.6	283	122.0	285	122.0	305
CHTR	4/18/05	106.8	288	31.7	289	74.1	271
Control	4/18/05	107.6	286	34.2	288	72.4	265
CHTR	4/25/05	122.0	253	122.0	260	122.0	263
Control	4/25/05	107.2	252	122.0	260	122.0	263

Appendix K: Post-treatment CHTR test fish building water temperature and dissolved oxygen measurements at 0, 24, and 48 h for the 2005 juvenile CH and CHTR trials

Treatment	Start Date	0 h		24 h		48 h	
		Water temperature (°C)	Dissolved oxygen (mg/L)	Water temperature (°C)	Dissolved oxygen (mg/L)	Water temperature (°C)	Dissolved oxygen (mg/L)
Control	5/16/05	16.69	8.45	15.22	8.14	15.44	7.43
CH	5/16/05	16.93	7.45	15.31	8.51	15.62	7.82
Control	5/17/05	15.12	8.89	15.16	8.18	15.52	7.93
CH	5/17/05	15.11	8.24	15.42	8.15	15.70	7.61
Control	5/24/05	18.03	7.88	20.11	6.22	19.81	7.20
CH	5/24/05	18.20	7.28	19.93	6.73	19.70	6.76
Control	6/06/05	16.76	7.83	16.84	8.20	18.85	7.23
CH	6/06/05	16.10	8.05	16.56	8.34	18.01	6.68
Control	6/07/05	16.81	8.74	18.86	7.19	16.81	6.83
CH	6/07/05	16.54	8.49	18.27	6.86	16.67	8.23
Control	6/08/05	18.50	7.94	17.64	9.17	17.98	8.85
CH	6/08/05	18.62	7.17	17.22	7.95	17.54	7.90
Control	6/13/05	19.79	8.36	19.86	6.44	19.76	7.41
CH	6/13/05	20.14	8.07	20.21	7.06	20.09	7.08
Control	6/14/05	19.30	7.28	19.65	7.15	20.20	6.78
CH	6/14/05	19.52	7.33	19.60	7.34	18.68	7.53
Control	6/15/05	19.93	7.38	20.29	7.23	20.06	7.09
CH	6/15/05	19.63	7.16	18.67	7.70	19.93	6.65
Control	6/28/05	20.58	7.74	20.39	7.34	20.48	7.94
CH	6/28/05	20.98	7.71	20.36	7.60	20.82	8.24
Control	6/28/05	21.73	7.39	20.94	7.55	21.81	8.36
CH	6/28/05	22.04	7.06	21.30	7.87	22.32	8.18
Control	7/11/05	20.80	7.63	21.73	7.09	22.66	6.31
CH	7/11/05	20.77	7.85	22.08	7.02	22.65	6.36
Control	7/11/05	20.74	7.63	22.04	6.95	22.60	6.21
CH	7/11/05	20.66	7.72	22.02	6.73	22.70	6.16
CHTR	5/18/05	16.36	7.76	15.94	7.43	15.97	7.46
Control	5/18/05	15.25	8.28	15.70	7.68	15.73	7.29
CHTR	5/23/05	17.07	7.52	17.92	7.38	20.00	8.01
Control	5/23/05	16.72	8.12	17.45	7.53	21.64	8.28
CHTR	5/31/05	17.23	9.35	16.82	9.46	17.54	7.55
Control	5/31/05	15.60	8.93	16.32	8.83	16.99	7.50
CHTR	6/06/05	17.00	7.49	17.00	8.44	18.80	6.56
Control	6/06/05	17.83	7.89	18.01	8.11	18.48	7.49
CHTR	6/07/05	17.33	8.34	18.74	6.45	17.05	6.80
Control	6/07/05	17.89	8.78	18.48	7.59	17.23	8.58

Appendix K: (continued)

Treatment	Start Date	0 h		24 h		48 h	
		Water temperature (°C)	Dissolved oxygen (mg/L)	Water temperature (°C)	Dissolved oxygen (mg/L)	Water temperature (°C)	Dissolved oxygen (mg/L)
CHTR	6/13/05	19.50	7.95	19.67	6.74	19.75	6.67
Control	6/13/05	18.76	8.38	18.98	6.47	18.63	7.09
CHTR	7/05/05	23.06	7.25	20.91	7.61	20.28	7.56
Control	7/05/05	22.46	7.30	21.30	7.18	20.75	6.96
CHTR	7/12/05	22.24	7.08	22.90	6.21	22.42	6.74
Control	7/12/05	20.85	7.55	22.72	6.35	22.32	6.40

Appendix L: Post-treatment CHTR test fish building water clarity and specific conductivity measurements at 0, 24, and 48 h for the 2005 juvenile CH and CHTR trials

Treatment	Start Date	0 h		24 h		48 h	
		Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)
Control	5/16/05	76.8	213.0	49.8	205.0	60.7	207.0
CH	5/16/05	71.8	215.0	56.2	205.0	63.1	207.0
Control	5/17/05	54.6	204.0	57.0	203.0	33.2	213.0
CH	5/17/05	50.2	205.0	67.6	207.0	30.3	204.0
Control	5/24/05	68.6	171.0	86.4	156.0	88.4	151.0
CH	5/24/05	75.1	170.0	69.3	156.0	92.1	150.0
Control	6/06/05	46.2	127.0	86.6	144.0	95.0	157.0
CH	6/06/05	62.9	123.0	82.1	141.0	96.8	155.0
Control	6/07/05	69.2	144.0	84.3	156.0	107.2	155.0
CH	6/07/05	78.0	141.0	89.8	157.0	115.5	155.0
Control	6/08/05	86.0	148.0	76.0	157.0	89.2	167.0
CH	6/08/05	96.0	151.0	96.8	158.0	93.8	166.0
Control	6/13/05	122.0	180.0	122.0	180.0	82.2	177.0
CH	6/13/05	122.0	182.0	122.0	182.0	79.1	178.0
Control	6/14/05	122.0	178.0	86.7	178.0	91.1	175.0
CH	6/14/05	122.0	179.0	83.3	177.0	75.5	169.0
Control	6/15/05	74.0	180.0	89.3	176.0	86.8	170.0
CH	6/15/05	79.0	177.0	78.9	169.0	95.2	169.0
Control	6/28/05	82.8	185.0	108.4	184.0	122.0	182.0
CH	6/28/05	74.2	186.0	108.2	183.0	122.0	183.0
Control	6/28/05	69.6	187.0	122.0	185.0	122.0	187.0
CH	6/28/05	71.6	188.0	122.0	185.0	122.0	189.0
Control	7/11/05	85.2	192.0	122.0	198.0	122.0	209.0
CH	7/11/05	98.3	192.0	122.0	199.0	122.0	196.0
Control	7/11/05	90.8	191.0	122.0	199.0	122.0	195.0
CH	7/11/05	109.4	191.0	122.0	199.0	122.0	196.0
CHTR	5/18/05	70.4	210.0	35.3	207.0	50.8	201.0
Control	5/18/05	62.1	205.0	31.9	204.0	53.6	200.0
CHTR	5/23/05	63.0	184.0	84.8	169.0	84.0	155.0
Control	5/23/05	54.6	183.0	70.1	166.0	97.8	164.0
CHTR	5/31/05	108.9	113.0	122.0	113.0	122.0	110.0
Control	5/31/05	99.1	126.0	122.0	111.0	122.0	109.0

Appendix L: (continued)

Treatment	Start Date	0 h		24 h		48 h	
		Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)
CHTR	6/06/05	44.1	127.0	86.3	145.0	90.4	155.0
Control	6/06/05	23.0	127.0	82.3	145.0	98.5	147.0
CHTR	6/07/05	76.8	155.0	78.1	152.0	108.3	156.0
Control	6/07/05	58.0	148.0	88.2	148.0	94.8	155.0
CHTR	6/13/05	122.0	179.0	122.0	179.0	81.0	178.0
Control	6/13/05	85.8	174.0	122.0	177.0	107.5	175.0
CHTR	7/05/05	86.2	205.0	61.8	204.0	83.2	190.0
Control	7/05/05	112.6	207.0	72.4	208.0	85.8	185.0
CHTR	7/12/05	122.0	199.0	122.0	196.0	122.0	189.0
Control	7/12/05	122.0	196.0	122.0	196.0	122.0	189.0

Appendix M: Post-treatment CHTR test fish building water temperature and dissolved oxygen measurements at 0, 24, and 48 h for the 2006 adult CH and CHTR trials

Treatment	Start Date	0 h		24 h		48 h	
		Water temp. (°C)	Dissolved oxygen (mg/L)	Water temp. (°C)	Dissolved oxygen (mg/L)	Water temp. (°C)	Dissolved oxygen (mg/L)
CH	12/20/05	10.34	10.87	10.60	10.78	11.05	10.01
Control	12/20/05	10.31	10.67	10.60	10.13	11.06	10.18
CH	12/21/05	10.80	9.57	11.17	9.72	11.61	9.59
Control	12/21/05	10.80	9.24	11.08	9.77	11.40	9.31
CH	1/03/06	11.04	10.22	11.19	10.01	10.98	10.19
Control	1/03/06	10.85	10.14	11.17	9.67	11.01	10.08
CH	1/04/06	11.04	10.20	10.90	10.27	11.12	8.54
Control	1/04/06	10.96	10.04	10.96	10.29	11.16	8.34
CH	1/10/06	10.73	9.30	10.85	9.39	10.79	10.49
Control	1/10/06	10.62	8.85	10.86	8.83	10.80	10.72
CH	1/11/06	10.97	9.08	10.83	11.82	10.92	9.61
Control	1/11/06	10.96	9.46	10.82	11.29	10.95	9.16
CH	1/17/06	10.09	11.89	10.42	10.31	9.94	10.40
Control	1/17/06	9.99	11.87	10.46	10.30	9.96	9.98
CH	1/17/06	10.44	11.33	10.63	10.39	10.25	9.68
Control	1/17/06	10.41	10.77	10.62	9.63	10.27	9.82
CH	1/18/06	10.61	11.22	10.25	10.49	10.33	10.28
Control	1/18/06	10.53	11.56	10.15	10.45	10.04	9.79
CH	1/23/06	9.67	10.94	9.49	10.56	9.53	10.73
Control	1/23/06	9.68	10.66	9.48	10.50	9.54	10.11
CH	1/23/06	9.93	10.66	9.71	10.41	9.71	10.08
Control	1/23/06	9.93	10.20	9.73	9.98	9.75	10.09
CH	1/24/06	9.58	11.07	9.64	10.55	10.10	10.45
Control	1/24/06	9.65	10.23	9.64	9.92	10.13	10.18
CH	1/30/06	11.18	10.78	10.54	10.09	10.89	9.92
Control	1/30/06	11.10	10.48	10.54	9.61	10.90	9.46
CH	2/21/06	10.34	9.83	10.54	10.52	10.87	9.48
Control	2/21/06	10.36	9.67	10.56	10.05	10.88	9.50
CH	2/22/06	10.72	10.62	10.88	9.41	10.96	9.59
Control	2/22/06	10.69	10.40	10.86	9.40	10.93	9.79
CH	2/22/06	10.59	10.91	10.86	9.44	10.92	9.72
Control	2/22/06	10.62	10.30	10.86	9.54	10.91	9.79
CH	3/07/06	11.76	10.56	11.22	9.93	11.76	9.75
Control	3/07/06	11.75	10.13	11.24	10.04	11.74	10.00
CH	3/08/06	11.23	10.55	11.74	9.96	10.78	10.01
Control	3/08/06	11.22	10.39	11.75	10.37	10.78	10.17

Appendix M: (continued)

Treatment	Start Date	0 h		24 h		48 h	
		Water temp. (°C)	Dissolved oxygen (mg/L)	Water temp. (°C)	Dissolved oxygen (mg/L)	Water temp. (°C)	Dissolved oxygen (mg/L)
CH	3/13/06	10.42	10.70	11.20	9.72	11.24	10.21
Control	3/13/06	10.44	10.97	11.20	9.99	11.25	10.19
CH	3/14/06	11.17	10.77	11.30	10.45	11.64	9.90
Control	3/14/06	11.12	10.53	11.30	10.14	11.64	10.27
CH	3/14/06	11.14	10.97	11.25	10.20	11.63	10.24
Control	3/14/06	11.15	10.83	11.31	10.69	11.65	10.21
CH	3/20/06	11.61	10.58	11.12	10.53	11.42	10.31
Control	3/20/06	11.61	10.16	11.10	9.93	11.49	10.30
CH	3/20/06	11.57	10.30	11.07	10.42	11.47	9.77
Control	3/20/06	11.60	10.01	11.09	9.70	11.48	9.94
CH	3/21/06	11.08	10.41	11.55	10.07	12.14	10.09
Control	3/21/06	11.03	10.36	11.53	10.07	12.07	10.48
CH	3/21/06	11.04	10.76	11.53	10.31	12.09	10.30
Control	3/21/06	11.02	10.50	11.53	10.12	12.13	9.88
CH	3/27/06	13.34	9.66	13.24	9.93	12.54	9.30
Control	3/27/06	13.23	9.64	13.19	8.81	12.52	9.34
CH	3/27/06	13.13	9.44	13.20	9.70	12.52	9.34
Control	3/27/06	13.26	9.94	13.19	9.06	12.57	8.75
CH	4/04/06	13.29	9.75	13.18	9.00	13.05	9.66
Control	4/04/06	13.29	10.07	13.14	9.02	13.02	9.30
CH	4/10/06	14.76	9.42	14.55	8.96	14.40	9.05
Control	4/10/06	14.76	8.88	14.55	8.33	14.40	8.37
CH	4/11/06	14.46	8.66	14.41	8.30	14.27	8.41
Control	4/11/06	14.47	8.28	14.40	8.41	14.27	8.33
CH	4/18/06	14.61	8.86	15.50	9.46	16.44	8.66
Control	4/18/06	14.67	8.90	15.48	10.05	16.39	9.26
CH	4/24/06	15.52	9.91	15.70	8.25	15.15	8.45
Control	4/24/06	15.54	8.72	15.84	8.56	15.16	8.94
CHTR	1/31/06	10.45	10.40	10.92	9.50	11.48	9.65
Control	1/31/06	10.45	10.64	10.93	9.37	11.51	10.26
CHTR	2/01/06	10.87	10.62	11.58	9.85	11.85	9.37
Control	2/01/06	10.88	10.50	11.54	9.56	11.86	9.34
CHTR	2/06/06	11.02	9.46	11.15	9.75	11.49	11.54
Control	2/06/06	11.12	9.63	11.16	10.31	11.56	11.37
CHTR	2/07/06	11.07	9.97	11.49	11.16	11.44	8.98
Control	2/07/06	11.09	10.09	11.48	11.40	11.46	9.57
CHTR	2/08/06	11.42	11.90	11.44	9.64	11.68	9.31
Control	2/08/06	11.41	11.43	11.44	9.49	11.67	9.47
CHTR	2/14/06	12.60	9.96	11.75	8.69	11.13	9.25

Appendix M: (continued)

Treatment	Start Date	0 h		24 h		48 h	
		Water temp. (°C)	Dissolved oxygen (mg/L)	Water temp. (°C)	Dissolved oxygen (mg/L)	Water temp. (°C)	Dissolved oxygen (mg/L)
Control	2/14/06	12.70	9.74	11.76	8.75	11.15	9.82
CHTR	2/15/06	11.75	8.96	11.25	9.21	11.22	9.00
Control	2/15/06	11.72	8.65	11.12	9.42	11.26	9.52
CHTR	3/22/06	11.46	10.42	12.11	9.98	12.89	9.79
Control	3/22/06	11.44	10.13	12.12	10.52	12.88	9.64
CHTR	3/28/06	13.17	10.38	12.51	9.90	12.65	9.65
Control	3/28/06	13.14	10.21	12.45	9.64	12.62	8.83
CHTR	4/19/06	15.45	9.57	16.38	9.12	15.81	8.87
Control	4/19/06	15.42	9.00	16.44	8.69	15.85	8.54
CHTR	4/25/06	15.78	8.97	15.22	8.54	16.26	8.83
Control	4/25/06	15.79	8.90	15.27	9.16	16.31	8.55
CHTR	5/02/06	19.05	8.20	18.66	7.29	17.87	8.11
Control	5/02/06	19.08	7.89	18.68	7.42	17.86	8.11
CHTR	5/03/06	18.52	8.13	17.85	8.09	17.85	7.83
Control	5/03/06	18.58	7.82	17.85	8.15	17.96	8.15

Appendix N: Post-treatment CHTR test fish building water clarity and specific conductivity measurements at 0, 24, and 48 h for the 2006 adult CH and CHTR trials

Treatment	Start Date	0 h		24 h		48 h	
		Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)
CH	12/20/05	76.1	406	122.0	411	122.0	417
Control	12/20/05	78.2	406	122.0	411	122.0	417
CH	12/21/05	60.0	460	122.0	418	122.0	423
Control	12/21/05	60.0	459	122.0	417	122.0	421
CH	1/03/06	68.2	241	64.4	233	50.2	188
Control	1/03/06	65.4	237	67.6	233	49.4	190
CH	1/04/06	61.4	235	57.2	190	81.6	193
Control	1/04/06	70.4	234	52.0	184	83.0	195
CH	1/10/06	60.6	121	73.4	124	77.6	125
Control	1/10/06	55.6	120	73.2	123	81.0	123
CH	1/11/06	76.8	123	74.8	129	84.7	128
Control	1/11/06	70.4	121	74.8	124	78.1	125
CH	1/17/06	78.2	137	60.0	146	12.2	144
Control	1/17/06	84.6	140	89.8	146	98.0	140
CH	1/17/06	81.6	138	89.4	147	92.0	141
Control	1/17/06	89.2	195	78.1	145	81.5	141
CH	1/18/06	85.2	146	95.8	141	99.2	144
Control	1/18/06	81.2	143	91.9	143	91.4	138
CH	1/23/06	87.4	167	88.6	179	77.8	195
Control	1/23/06	87.8	166	91.6	183	82.4	195
CH	1/23/06	76.8	166	95.6	181	94.6	197
Control	1/23/06	92.2	164	89.2	180	93.4	197
CH	1/24/06	95.2	183	74.5	196	122.0	202
Control	1/24/06	93.2	184	83.2	196	122.0	202
CH	1/30/06	122.0	214	122.0	214	122.0	218
Control	1/30/06	122.0	213	122.0	214	122.0	218
CH	2/21/06	122.0	192	122.0	197	122.0	187
Control	2/21/06	122.0	192	122.0	198	122.0	181
CH	2/22/06	122.0	189	122.0	184	122.0	188
Control	2/22/06	122.0	195	122.0	181	122.0	195
CH	2/22/06	122.0	187	122.0	182	122.0	195
Control	2/22/06	122.0	194	122.0	182	122.0	190
CH	3/07/06	122.0	195	0.0	174	122.0	159
Control	3/07/06	122.0	195	0.0	171	122.0	167
CH	3/08/06	0.0	165	0.0	156	122.0	147
Control	3/08/06	0.0	167	0.0	159	122.0	152
CH	3/13/06	122.0	142	122.0	145	122.0	151
Control	3/13/06	122.0	142	122.0	144	122.0	151

Appendix N: (continued)

Treatment	Start Date	0 h		24 h		48 h	
		Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)
CH	3/14/06	122.0	139	122.0	151	122.0	158
Control	3/14/06	122.0	150	122.0	148	122.0	157
CH	3/14/06	122.0	144	122.0	154	122.0	157
Control	3/14/06	122.0	145	122.0	149	122.0	157
CH	3/20/06	122.0	152	122.0	156	122.0	166
Control	3/20/06	122.0	153	122.0	147	122.0	169
CH	3/20/06	122.0	154	122.0	142	122.0	170
Control	3/20/06	122.0	149	122.0	147	122.0	159
CH	3/21/06	122.0	143	122.0	160	122.0	167
Control	3/21/06	122.0	143	122.0	169	122.0	167
CH	3/21/06	122.0	155	122.0	158	122.0	166
Control	3/21/06	122.0	149	122.0	173	122.0	171
CH	3/27/06	122.0	167	122.0	164	122.0	166
Control	3/27/06	122.0	173	122.0	163	122.0	168
CH	3/27/06	101.2	166	122.0	165	122.0	161
Control	3/27/06	122.0	167	122.0	173	122.0	160
CH	4/04/06	122.0	140	0.0	145	122.0	140
Control	4/04/06	108.0	123	91.0	148	122.0	139
CH	4/10/06	122.0	131	122.0	132	74.4	136
Control	4/10/06	122.0	142	122.0	135	85.8	133
CH	4/11/06	102.0	132	84.6	133	96.2	121
Control	4/11/06	113.8	131	86.8	136	110.0	120
CH	4/18/06	122.0	152	122.0	130	122.0	133
Control	4/18/06	122.0	125	122.0	126	122.0	134
CH	4/24/06	122.0	110	122.0	101	122.0	100
Control	4/24/06	122.0	113	122.0	114	122.0	98
CHTR	1/31/06	122.0	213	122.0	218	60.0	232
Control	1/31/06	122.0	213	122.0	218	92.4	231
CHTR	2/01/06	107.0	217	101.8	232	91.3	235
Control	2/01/06	102.0	217	122.0	231	60.0	234
CHTR	2/06/06	115.0	252	60.0	223	60.0	241
Control	2/06/06	122.0	225	79.4	223	122.0	222
CHTR	2/07/06	88.2	222	60.0	221	122.0	221
Control	2/07/06	60.0	222	60.0	221	122.0	221
CHTR	2/08/06	60.0	222	122.0	221	60.0	222
Control	2/08/06	60.0	221	122.0	221	60.0	222
CHTR	2/14/06	60.0	225	82.0	220	122.0	213
Control	2/14/06	122.0	225	60.0	221	122.0	213

Appendix N: (continued)

Treatment	Start Date	0 h		24 h		48 h	
		Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)
CHTR	2/15/06	60.0	241	60.0	212	122.0	206
Control	2/15/06	77.1	220	122.0	212	60.0	207
CHTR	3/22/06	122.0	165	122.0	170	122.0	174
Control	3/22/06	122.0	164	122.0	171	122.0	174
CHTR	3/28/06	122.0	170	122.0	163	122.0	160
Control	3/28/06	122.0	168	122.0	160	122.0	157
CHTR	4/19/06	122.0	126	122.0	130	122.0	130
Control	4/19/06	122.0	132	122.0	130	122.0	129
CHTR	4/25/06	122.0	162	122.0	100	122.0	103
Control	4/25/06	122.0	119	122.0	102	122.0	104
CHTR	5/02/06	122.0	145	122.0	107	122.0	104
Control	5/02/06	122.0	103	122.0	100	122.0	102
CHTR	5/03/06	122.0	153	122.0	105	122.0	103
Control	5/03/06	122.0	101	122.0	100	122.0	105

Appendix O: Post-treatment CHTR test fish building water temperature and dissolved oxygen measurements at 0, 24, and 48 h for the 2006 juvenile CH and CHTR trials

Treatment	Start Date	0 h		24 h		48 h	
		Water temp. (°C)	Dissolved oxygen (mg/L)	Water temp. (°C)	Dissolved oxygen (mg/L)	Water temp. (°C)	Dissolved oxygen (mg/L)
CH	6/12/06	19.38	7.74	19.37	7.87	19.20	8.39
Control	6/12/06	19.33	7.79	19.36	7.77	19.14	8.13
CH	6/13/06	19.26	6.87	19.23	6.90	18.98	7.95
Control	6/13/06	19.30	6.93	19.16	6.79	18.72	7.62
CH	6/14/06	19.31	8.07	18.81	7.77	18.36	8.16
Control	6/14/06	19.32	7.75	18.68	7.83	18.28	8.08
CH	6/19/06	19.31	7.90	18.44	7.76	17.56	8.26
Control	6/19/06	17.81	7.83	17.36	7.93	17.83	7.86
CH	6/20/06	18.67	8.47	17.62	7.95	18.31	7.53
Control	6/20/06	19.15	8.65	17.81	8.16	18.43	7.49
CH	6/26/06	20.76	7.01	0.0	0.0	19.78	7.48
Control	6/26/06	20.53	6.85	19.35	6.87	19.81	7.04
CH	6/27/06	20.21	7.66	20.45	7.17	20.36	6.86
Control	6/27/06	19.57	8.09	20.46	7.46	20.38	7.39
CH	6/28/06	20.93	7.50	20.42	6.33	20.38	6.60
Control	6/28/06	21.09	8.03	20.41	7.45	20.48	7.30
CH	6/28/06	20.02	7.74	19.53	7.14	20.67	7.09
Control	6/28/06	20.12	8.07	20.01	7.95	20.48	7.60
CH	7/03/06	22.10	6.17	20.95	7.02	21.15	6.83
Control	7/03/06	21.74	6.49	21.00	6.88	21.93	6.49
CH	7/05/06	21.82	6.30	21.22	7.37	20.97	7.48
Control	7/05/06	21.90	6.84	21.23	7.23	20.97	7.37
CH	7/05/06	20.62	6.89	20.99	7.33	19.67	7.25
Control	7/05/06	21.14	6.92	21.34	7.31	20.42	7.25
CH	7/10/06	21.91	6.47	19.70	7.18	20.58	7.54
Control	7/10/06	22.01	6.89	21.62	7.06	21.67	7.38
CH	7/11/06	19.87	7.08	20.33	7.38	20.00	7.22
Control	7/11/06	21.55	7.16	20.58	7.61	20.34	7.44
CH	7/12/06	20.61	7.56	19.60	7.28	19.24	7.08
Control	7/12/06	21.63	7.71	20.22	7.79	19.97	7.43
CHTR	6/05/06	20.11	7.97	19.40	7.84	19.21	7.73
Control	6/05/06	19.99	7.89	19.10	7.93	19.17	7.89
CHTR	6/26/06	20.81	7.18	19.89	7.11	19.85	7.39
Control	6/26/06	20.05	8.08	19.92	6.83	20.06	7.44
CHTR	6/27/06	20.79	6.45	20.80	7.04	19.48	6.88

Appendix O: (continued)

Treatment	Start Date	0 h		24 h		48 h	
		Water temp. (°C)	Dissolved oxygen (mg/L)	Water temp. (°C)	Dissolved oxygen (mg/L)	Water temp. (°C)	Dissolved oxygen (mg/L)
Control	6/27/06	19.78	7.69	19.98	7.19	19.90	6.66
CHTR	7/03/06	21.62	6.12	21.08	6.76	21.92	6.50
Control	7/03/06	21.58	6.26	21.08	7.13	21.90	6.68
CHTR	7/10/06	21.87	7.17	21.71	6.83	21.67	7.04
Control	7/10/06	21.92	6.91	21.68	7.07	21.64	7.22
CHTR	7/11/06	21.90	6.53	21.66	7.13	20.49	7.64
Control	7/11/06	21.60	7.11	20.67	7.39	20.29	7.25
CHTR	7/12/06	21.49	6.88	20.47	7.18	20.54	6.67
Control	7/12/06	21.56	7.60	20.23	7.68	20.42	7.42

Appendix P: Post-treatment CHTR test fish building water clarity and specific conductivity measurements at 0, 24, and 48 h for the 2006 juvenile CH and CHTR trials

		0 h		24 h		48 h	
Treatment	**Start Date**	**Water clarity (cm)**	**Specific conductivity (µS/cm)**	**Water clarity (cm)**	**Specific conductivity (µS/cm)**	**Water clarity (cm)**	**Specific conductivity (µS/cm)**
CH	6/12/06	47.9	108.0	64.4	100.0	85.6	100.0
Control	6/12/06	0.0	108.0	61.4	101.0	85.4	98.0
CH	6/13/06	70.0	97.0	99.4	98.0	101.0	95.0
Control	6/13/06	64.6	101.0	90.8	98.0	105.6	94.0
CH	6/14/06	92.6	99.0	100.8	94.0	122.0	93.0
Control	6/14/06	80.1	98.0	100.5	94.0	122.0	93.0
CH	6/19/06	28.8	97.0	71.0	97.0	122.0	98.0
Control	6/19/06	0.0	93.0	71.8	95.0	122.0	98.0
CH	6/20/06	68.1	97.0	101.2	98.0	104.1	112.0
Control	6/20/06	45.0	98.0	109.8	98.0	117.7	112.0
CH	6/26/06	80.3	123.0	0.0	0.0	84.0	111.0
Control	6/26/06	87.8	124.0	96.9	115.0	86.8	111.0
CH	6/27/06	75.2	119.0	93.5	111.0	112.2	111.0
Control	6/27/06	43.9	118.0	97.2	111.0	115.0	111.0
CH	6/28/06	56.6	114.0	94.2	110.0	99.0	111.0
Control	6/28/06	54.1	115.0	94.4	110.0	92.1	111.0
CH	6/28/06	62.2	111.0	120.4	108.0	122.0	112.0
Control	6/28/06	92.6	111.0	105.1	109.0	122.0	111.0
CH	7/03/06	78.4	142.0	105.1	145.0	23.7	145.0
Control	7/03/06	68.6	140.0	103.9	145.0	21.9	148.0
CH	7/05/06	24.0	147.0	27.4	149.0	61.3	156.0
Control	7/05/06	24.4	147.0	26.8	150.0	58.8	156.0
CH	7/05/06	21.0	142.0	24.7	146.0	66.7	149.0
Control	7/05/06	23.9	145.0	28.0	147.0	61.5	153.0
CH	7/10/06	88.8	154.0	67.4	149.0	20.1	155.0
Control	7/10/06	89.2	154.0	69.6	153.0	26.1	157.0
CH	7/11/06	48.4	150.0	19.1	153.0	59.4	138.0
Control	7/11/06	71.0	153.0	21.8	155.0	59.7	140.0
CH	7/12/06	21.2	158.0	69.4	137.0	95.6	143.0
Control	7/12/06	24.6	159.0	57.1	140.0	98.0	145.0
CHTR	6/05/06	110.0	155.0	71.4	108.0	87.8	108.0
Control	6/05/06	111.4	135.0	79.6	108.0	97.8	107.0
CHTR	6/26/06	86.5	183.0	95.8	117.0	83.6	111.0
Control	6/26/06	81.8	126.0	94.9	117.0	88.6	111.0
CHTR	6/27/06	73.8	183.0	89.4	117.0	110.5	108.0

Appendix P: (continued)

Treatment	Start Date	0 h		24 h		48 h	
		Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)	Water clarity (cm)	Specific conductivity (µS/cm)
Control	6/27/06	80.8	117.0	80.2	111.0	88.4	109.0
CHTR	7/03/06	64.0	201.0	105.0	146.0	23.7	149.0
Control	7/03/06	71.8	140.0	106.2	146.0	27.8	148.0
CHTR	7/10/06	77.9	211.0	67.1	153.0	24.6	158.0
Control	7/10/06	91.4	154.0	67.7	153.0	28.3	157.0
CHTR	7/11/06	60.2	167.0	23.8	157.0	59.7	140.0
Control	7/11/06	73.3	153.0	21.2	156.0	57.2	141.0
CHTR	7/12/06	25.8	200.0	54.1	140.0	87.3	147.0
Control	7/12/06	26.2	160.0	59.5	140.0	98.5	147.0

Appendix Q: Adult survival – descriptive statistics

Year	Treatment	Hour	N	Min	Max	Mean	Variance
2005	CH	0	6	76.9	100.0	94.1	81.21
2005	Control	0	6	100.0	100.0	100.0	0.00
2005	CH	24	6	76.9	100.0	94.1	81.21
2005	Control	24	6	95.7	100.0	99.3	3.08
2005	CH	48	6	76.9	100.0	93.5	74.73
2005	Control	48	6	95.7	100.0	99.3	3.08
2005	CHTR	0	4	84.6	100.0	93.3	62.84
2005	Control	0	4	95.7	100.0	98.9	4.62
2005	CHTR	24	4	84.6	100.0	93.3	62.84
2005	Control	24	4	95.7	100.0	98.9	4.62
2005	CHTR	48	4	84.6	100.0	93.3	62.84
2005	Control	48	4	91.3	100.0	97.8	18.92
2006	CH	0	32	9.5	100.0	88.9	426.64
2006	Control	0	32	94.4	100.0	99.8	0.98
2006	CH	24	32	9.5	100.0	88.4	427.28
2006	Control	24	32	94.4	100.0	99.7	1.90
2006	CH	48	32	9.5	100.0	88.3	430.30
2006	Control	48	32	94.4	100.0	99.7	1.90
2006	CHTR	0	13	22.7	100.0	86.7	541.23
2006	Control	0	13	100.0	100.0	100.0	0.00
2006	CHTR	24	13	18.2	100.0	85.7	572.74
2006	Control	24	13	100.0	100.0	100.0	0.00
2006	CHTR	48	13	18.2	100.0	85.3	566.97
2006	Control	48	13	100.0	100.0	100.0	0.00

Appendix R: Juvenile survival – descriptive statistics

Year	Treatment	Hour	N	Min	Max	Mean	Variance
2005	CH	0	13	39.5	94.4	71.8	239.54
2005	Control	0	13	95.7	100.0	99.0	3.56
2005	CH	24	13	33.3	94.4	62.6	398.85
2005	Control	24	13	73.9	100.0	84.9	61.73
2005	CH	48	13	27.8	94.4	61.3	416.70
2005	Control	48	13	73.9	100.0	84.2	65.06
2005	CHTR	0	8	11.1	88.9	50.6	729.53
2005	Control	0	8	91.3	100.0	96.7	9.47
2005	CHTR	24	8	5.6	83.3	38.8	787.57
2005	Control	24	8	47.8	100.0	81.0	274.54
2005	CHTR	48	8	5.6	83.3	37.4	802.51
2005	Control	48	8	43.5	91.7	78.3	259.62
2006	CH	0	15	60.8	97.2	80.2	109.73
2006	Control	0	15	95.7	100.0	99.5	1.99
2006	CH	24	15	21.6	77.8	54.6	325.32
2006	Control	24	15	78.3	100.0	91.8	66.36
2006	CH	48	15	16.7	77.8	50.9	408.69
2006	Control	48	15	60.9	100.0	86.0	225.64
2006	CHTR	0	7	18.4	100.0	78.4	768.40
2006	Control	0	7	100.0	100.0	100.0	0.00
2006	CHTR	24	7	10.5	88.9	61.4	678.05
2006	Control	24	7	78.3	100.0	92.5	61.05
2006	CHTR	48	7	10.5	80.6	57.9	599.83
2006	Control	48	7	52.2	100.0	85.7	275.06

Appendix S: Adult fish injury – descriptive statistics

Year	Treatment	Hour	N	Min	Max	Mean	Variance
2005	QC	0	6	0.0	25.0	8.3	166.67
2005	Control	48	6	0.0	33.3	8.3	194.42
2005	CH	48	6	0.0	33.3	13.5	266.77
2005	QC	0	4	0.0	25.0	6.3	156.25
2005	Control	48	4	0.0	16.7	4.2	069.47
2005	CHTR	48	4	0.0	33.3	12.5	254.59
2006	QC	0	32	0.0	100.0	35.2	760.46
2006	Control	48	32	0.0	83.3	28.6	559.74
2006	CH	48	32	0.0	83.3	34.6	563.21
2006	QC	0	13	0.0	100.0	55.8	1266.03
2006	Control	48	13	0.0	83.3	44.9	573.36
2006	CHTR	48	13	16.7	100.0	41.2	623.76

Appendix T: Juvenile fish injury – descriptive statistics

Year	Treatment	Hour	N	Min	Max	Mean	Variance
2005	QC	0	13	0.0	75.0	25.0	937.50
2005	Control	48	13	0.0	83.3	44.9	573.36
2005	CH	48	13	16.7	100.0	41.2	623.76
2005	QC	0	8	0.0	100.0	15.6	1238.84
2005	Control	48	8	0.0	33.3	6.3	153.75
2005	CHTR	48	8	0.0	100.0	25.0	1428.57
2006	QC	0	16	0.0	50.0	18.8	375.00
2006	Control	48	16	0.0	33.3	11.5	137.73
2006	CH	48	16	0.0	33.3	14.6	180.53
2006	QC	0	7	0.0	40.0	12.9	282.14
2006	Control	48	7	0.0	33.3	11.9	251.28
2006	CHTR	48	7	0.0	50.0	19.5	316.38

Appendix U: Adult scale loss – descriptive statistics

Year	Treatment	Hour	N	Min	Max	Mean	Variance
2005	QC	0	6	0.00	0.18	0.063	0.004
2005	Control	48	6	0.02	0.09	0.058	0.001
2005	CH	48	6	0.02	0.23	0.100	0.006
2005	QC	0	4	0.08	0.15	0.110	0.001
2005	Control	48	4	0.04	0.21	0.100	0.006
2005	CHTR	48	4	0.01	0.64	0.282	0.088
2006	QC	0	32	0.00	2.33	0.261	0.243
2006	Control	48	32	0.00	0.97	0.234	0.059
2006	CH	48	32	0.00	2.37	0.587	0.631
2006	QC	0	13	0.04	1.82	0.579	0.297
2006	Control	48	13	0.14	2.41	0.640	0.379
2006	CHTR	48	13	0.14	1.97	0.609	0.268

Appendix V: Recovery and survival rates in adult 2005 CH and CHTR trials

Date	Treatment	Recovery (%)	Control survival (%)			Treatment survival (%)		
			0 h	24 h	48 h	0 h	24 h	48 h
4/11/05	CHTR	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4/12/05	CHTR	84.6	95.7	95.7	91.3	84.6	84.6	84.6
4/18/05	CHTR	88.5	100.0	100.0	100.0	88.5	88.5	88.5
4/25/05	CHTR	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4/06/05	CH	95.7	100.0	100.0	100.0	95.7	95.7	95.7
4/12/05	CH	96.2	100.0	100.0	100.0	92.3	92.3	92.3
4/20/05	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4/20/05	CH	84.6	100.0	100.0	100.0	76.9	76.9	76.9
4/25/05	CH	100.0	100.0	95.7	95.7	100.0	100.0	96.2
4/27/05	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Appendix W: Recovery and survival rates in adult 2006 CH and CHTR trials

Date	Treatment	Recovery (%)	Control survival (%)			Treatment survival (%)		
			0 h	24 h	48 h	0 h	24 h	48 h
1/31/06	CHTR	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2/01/06	CHTR	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2/06/06	CHTR	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2/07/06	CHTR	100.0	100.0	100.0	100.0	95.2	95.2	95.2
2/08/06	CHTR	100.0	100.0	100.0	100.0	100.0	95.5	95.5
2/14/06	CHTR	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2/15/06	CHTR	100.0	100.0	100.0	100.0	95.2	95.2	95.2
3/22/06	CHTR	100.0	100.0	100.0	100.0	85.7	85.7	85.7
3/28/06	CHTR	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4/19/06	CHTR	100.0	100.0	100.0	100.0	100.0	95.2	90.5
4/25/06	CHTR	22.7	100.0	100.0	100.0	22.7	18.2	18.2
5/02/06	CHTR	61.9	100.0	100.0	100.0	61.9	61.9	61.9
5/03/06	CHTR	66.7	100.0	100.0	100.0	66.7	66.7	66.7
12/20/05	CH	100.0	100.0	100.0	100.0	100.0	95.5	95.5
12/21/05	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/03/06	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/04/06	CH	95.2	100.0	100.0	100.0	90.5	90.5	90.5
1/10/06	CH	85.7	100.0	100.0	100.0	85.7	85.7	85.7
1/11/06	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/17/06	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/17/06	CH	100.0	100.0	100.0	100.0	90.9	90.9	90.9
1/18/06	CH	100.0	94.4	94.4	94.4	100.0	100.0	100.0
1/23/06	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/23/06	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Appendix W: (continued)

Date	Treatment	Recovery (%)	Control survival (%)			Treatment survival (%)		
			0 h	24 h	48 h	0 h	24 h	48 h
1/30/06	CH	100.0	100.0	100.0	100.0	95.5	95.5	95.5
2/21/06	CH	100.0	100.0	100.0	100.0	95.2	95.2	95.2
2/22/06	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2/22/06	CH	100.0	100.0	94.4	94.4	100.0	100.0	100.0
3/07/06	CH	90.5	100.0	100.0	100.0	90.5	90.5	90.5
3/08/06	CH	100.0	100.0	100.0	100.0	95.2	95.2	95.2
3/13/06	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3/14/06	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3/14/06	CH	90.5	100.0	100.0	100.0	81.0	81.0	76.2
3/20/06	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3/20/06	CH	42.9	100.0	100.0	100.0	38.1	38.1	38.1
3/21/06	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3/21/06	CH	95.2	100.0	100.0	100.0	95.2	95.2	95.2
3/27/06	CH	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3/27/06	CH	81.0	100.0	100.0	100.0	81.0	81.0	81.0
4/04/06	CH	90.5	100.0	100.0	100.0	81.0	76.2	76.2
4/10/06	CH	42.9	100.0	100.0	100.0	42.9	42.9	42.9
4/11/06	CH	14.3	100.0	100.0	100.0	9.5	9.5	9.5
4/18/06	CH	90.5	100.0	100.0	100.0	90.5	90.5	90.5
4/24/06	CH	90.5	100.0	100.0	100.0	90.5	85.7	85.7

Appendix X: Recovery and survival rates in juvenile 2005 CH and CHTR trials

Date	Treatment	Recovery (%)	Control survival (%)			Treatment survival (%)		
			0 h	24 h	48 h	0 h	24 h	48 h
5/18/05	CHTR	36.8	95.5	81.8	81.8	36.8	34.2	31.6
5/23/05	CHTR	21.1	95.7	69.6	69.6	21.1	10.5	10.5
5/31/05	CHTR	58.3	95.7	95.7	91.3	58.3	50.0	47.2
6/06/05	CHTR	88.9	95.7	91.3	91.3	88.9	83.3	83.3
6/07/05	CHTR	58.3	100.0	82.6	78.3	58.3	41.7	38.9
6/13/05	CHTR	11.1	100.0	79.2	79.2	11.1	5.6	5.6
7/05/05	CHTR	80.6	100.0	100.0	91.7	80.6	69.4	69.4
7/12/05	CHTR	50.0	91.3	47.8	43.5	50.0	15.6	12.5
5/16/05	CH	39.5	100.0	73.9	73.9	39.5	39.5	39.5
5/17/05	CH	52.8	100.0	91.3	91.3	52.8	50.0	50.0
5/24/05	CH	80.6	100.0	87.0	87.0	80.6	72.2	69.4
6/06/05	CH	66.7	100.0	73.9	73.9	66.7	58.3	58.3
6/07/05	CH	77.8	100.0	82.6	78.3	77.8	66.7	66.7
6/08/05	CH	75.0	95.7	87.0	87.0	75.0	75.0	75.0
6/13/05	CH	66.7	100.0	95.7	95.7	66.7	33.3	33.3
6/14/05	CH	60.0	100.0	78.3	78.3	60.0	48.6	48.6
6/15/05	CH	83.3	100.0	86.4	81.8	83.3	83.3	80.6
6/28/05	CH	70.6	100.0	82.6	82.6	70.6	70.6	70.6
6/28/05	CH	94.4	95.7	78.3	78.3	94.4	86.1	83.3
7/11/05	CH	94.4	100.0	100.0	100.0	94.4	94.4	94.4
7/11/05	CH	72.2	95.7	87.0	87.0	72.2	36.1	27.8

Appendix Y: Recovery and survival rates in juvenile 2006 CH and CHTR trials

Date	Treatment	Recovery (%)	Control survival (%)			Treatment survival (%)		
			0 h	24 h	48 h	0 h	24 h	48 h
6/05/06	CHTR	57.9	100.0	87.0	87.0	18.4	10.5	10.5
6/26/06	CHTR	86.1	100.0	95.7	91.3	77.8	58.3	58.3
6/27/06	CHTR	100.0	100.0	100.0	100.0	100.0	88.9	72.2
7/03/06	CHTR	100.0	100.0	100.0	100.0	94.4	80.6	80.6
7/10/06	CHTR	97.2	100.0	91.3	91.3	91.7	75.0	75.0
7/11/06	CHTR	88.9	100.0	95.7	78.3	88.9	66.7	66.7
7/12/06	CHTR	91.7	100.0	78.3	52.2	77.8	50.0	41.7
6/12/06	CH	69.4	96.3	96.3	96.3	66.7	50.0	47.2
6/13/06	CH	83.3	100.0	100.0	100.0	80.6	75.0	75.0
6/14/06	CH	91.7	100.0	80.0	80.0	91.7	75.0	75.0
6/19/06	CH	85.1	100.0	96.3	92.6	60.8	21.6	18.9
6/20/06	CH	94.4	100.0	100.0	100.0	86.1	41.7	41.7
6/26/06	CH	83.3	100.0	100.0	100.0	77.8	77.8	77.8
6/27/06	CH	88.9	100.0	100.0	100.0	86.1	69.4	69.4
6/28/06	CH	83.3	100.0	100.0	100.0	83.3	55.6	47.2
6/28/06	CH	88.9	95.7	82.6	73.9	86.1	72.2	63.9
7/03/06	CH	72.2	100.0	87.0	87.0	66.7	41.7	36.1
7/05/06	CH	97.2	100.0	91.3	60.9	88.9	36.1	27.8
7/05/06	CH	83.3	100.0	78.3	65.2	69.4	55.6	47.2
7/10/06	CH	91.7	100.0	95.7	95.7	86.1	52.8	52.8
7/11/06	CH	100.0	100.0	87.0	78.3	97.2	66.7	66.7
7/12/06	CH	86.1	100.0	82.6	60.9	75.0	27.8	16.7

Appendix Z: Percent deviation results for water quality and fish measurements

Parameter	N	Range of deviation	Mean % deviation	Standard deviation	Number exceeding 5%
Water temperature	55	0 - 5.61	0.59	1.07	1
Dissolved oxygen	55	0 - 15.03	3.60	3.17	11
Specific conductivity	55	0 - 35.35	2.19	5.27	6
Water clarity	52	0 - 17.33	3.12	4.71	10
Fish fork length	262	0 - 7.69	0.28	0.95	1
Fish weight	262	0 - 9.09	0.49	1.36	4